TRANSACTIONS

OF

# THE AMERICAN SOCIETY

OF

# HEATING AND VENTILATING ENGINEERS

VOL. XI.

ELEVENTH ANNUAL MEETING
NEW YORK, JANUARY 17-19, 1905

SUMMER MEETING
CHICAGO, ILL., JULY 7-8, 1905

PUBLISHED BY THE SOCIETY
AT THE OFFICE OF THE SECRETARY
NEW YORK CITY

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# CONTENTS.

CXXXIV.

# THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

## ELEVENTH ANNUAL MEETING.

Held in the Hotel Astor, New York City, January 17, 18, 19, 1905.

## PROCEEDINGS.

### FIRST SESSION.

Tuesday, January 17, 1905.

The Eleventh Annual Meeting of the American Society of Heating and Ventilating Engineers was called to order in the "Hotel Astor," New York City, January 17, 1905, at 2.40 P.M., by the President of the Society, Mr. Andrew Harvey, of Detroit, Mich.

Secretary Mackay called the roll, and reported a quorum present. Before calling the roll, however, Secretary Mackay announced the names of those elected to membership since the last meeting, as follows:

| | | |
|---|---|---|
| Hugo Erich von Boehmer, | Berlin, Germany, | Member. |
| Ralph Collamore, | Detroit, Mich., | " |
| Bert C. Davis, | Kansas City, Mo., | " |
| Thomas M. Dick, | Brooklyn, N. Y., | " |
| James A. Donnelly, | New York, | " |
| Howard H. Fielding, | Denver, Colo., | " |
| Bernard Gause, | Jacksonville, Ill., | " |
| Walter Jones, | Stourbridge, England, | " |
| Joseph P. Lisk, | Troy, N. Y., | " |
| Lucien Rouquaud, | Paris, France, | " |
| Fred R. Still, | Detroit, Mich., | " |
| Ralph S. Thompson, | Springfield, O., | " |
| Joseph Graham, | New York, | Associate. |
| James M. Heatherton, | New York, | " |
| Robt. K. Story, | New York, | " |
| Cornelis M. Slotboom, | New York, | Junior |

On motion, the reading of the minutes was dispensed with. President Harvey then read the following address:

## PRESIDENT'S ADDRESS.

*Members of the American Society of Heating and Ventilating Engineers:*

I fully appreciate the honor which gives me the privilege of welcoming you to this our eleventh annual meeting. Some of you may not know the reason why we have met in this place, instead of holding our annual meeting in the hall of the American Society of Mechanical Engineers, as we have done in the past. Your Board of Governors at its meeting in September were informed that in all probability the old building in which these meetings have been held would be torn down during this year and thought it best to try the experiment of holding this annual meeting in a hotel, so as to make this fact more prominent, and to give the members an opportunity of taking whatever action they might think would be for the best interest of this Society. It will be necessary to arrange some suitable place for holding our meetings, at least until the new Carnegie Engineering Building is completed, on condition that satisfactory arrangements can be made, which may mean several years.

I desire to express my appreciation to the officers and members of the Society on the efficient manner in which the suggestion of making the anniversary of the tenth meeting prominent in the history of the Society, and now, as we have entered the second ten years with the knowledge of success of the past before us, what may we not expect in the coming years? We have among our members most of the best known heating and ventilating engineers of this country and quite a number from foreign countries. I believe about ten per cent. of our members are foreigners, and this fact suggests a point which may be worth considering at some time in the near future. That is, would it not be for the best interest of this Society to hold a summer meeting in some city in Europe, so as to give the American members an opportunity of meeting our foreign brothers in their own country? I am sure that every member who could go over there would find it one of the best investments he had ever made. Most of all of the other American Engineering societies have done so in past years, and have been much benefited by the results.

I must congratulate the members on having accomplished one of the most important acts this past year that has ever been obtained by this Society since its organization. That is the adoption by the New York Legislature of a State law last April for the proper construction and ventilation for school buildings, which is the result of the persistent and untiring efforts of our Eastern members, and is surely a very creditable accomplishment and adds much to the reputation of the Society. I trust that within the next ten years the people of every State in the Union will have become so well informed of the necessity for properly ventilated schools and public buildings that it will be considered as great a crime to construct these buildings without providing for sufficient and proper ventilation as it would be to erect a building without a proper foundation. The information the law-makers of the State require must be supplied by the heating and ventilating engineers of this Society, and this fact should inspire every member to do his best.

I am also pleased to state that the financial affairs of the Society are in better condition than ever before. The membership has increased by thirty during the past year, although the aim of the Society has always been for the quality of its members and not the quantity.

ANDREW HARVEY,
President.

Secretary Mackay read the following report:

SECRETARY'S REPORT.

*The American Society of Heating and Ventilating Engineers:*

Gentlemen: Your Secretary would report an increase in membership during the past year. At our last annual meeting our membership was composed of 185 members, 1 honorary member, 15 associates and 3 juniors, or a total of 204 members of all grades. During the year we have added 24 members, 4 associates and 2 juniors. Two members failed to qualify, 5 members have been dropped from the roll for non-payment of dues, 5 members have resigned and 2 members have died since the last annual meeting—Mr. Stephen G. Clark, who became a member on December 29, 1902, died on February 3, 1904, and Mr. Chas. M.

Wilkes, who became a member in January, 1897, died January 7, 1905. Our present membership is 198 members, 1 honorary member, 16 associate and 5 juniors, or a total of 220 members of all grades, making a net increase of 16 during the past year, in addition to which we have a number of applications to be acted upon and voted on after the annual meeting.

The financial affairs of the Society are in good condition. At the last annual meeting there was a balance in the hands of the Treasurer of $543.49. We have received from all sources during the past year $2,414.99, which, with the balance on hand, made a total of $2,958.48 available.

The expenditures amounted to $2,274.20, leaving a balance in the hands of the Treasurer of $684.19.

There is a balance owing from members for dues and from newly-elected candidates for membership for initiation fees and dues, amounting to $655, which, with the balance on hand, amounts to $1,339.19.

We have no unpaid bills except those in connection with the present meeting, which have not been presented, except the Secretary's account, amounting to $100.74. Deducting this, with the amount on hand and owing from members and others, leaves a balance of $1,229.63.

The members dropped from the rolls during the year owed the Society a total of $150.

The Secretary's expenses for the year, including stenographer, clerk hire, rent of post-office box, expenses in connection with the summer meeting, postage, expressage, etc., amount to $587.21.

The 1904 Proceedings have been edited, they are now being corrected, and will be forwarded to the members as soon after this meeting as possible. The cost of the editing and printing of these Proceedings will amount to about $900.

The Society held a successful meeting at Detroit, Mich., July 15 and 16, 1904.

All the papers to be presented at this meeting, with the exception of one, which will be read from manuscript, while received late, have been printed and forwarded to the members.

Respectfully submitted,

W. M. Mackay,

Secretary.

Treasurer U. G. Scollay read the following report:

TREASURER'S REPORT.

| | | | |
|---|---|---|---|
| Balance on hand February 5, 1904 | | $543 49 | |
| Cash received since February 5, 1904: | | | |
| Dues | $1,897 67 | | |
| Initiation fees | 370 00 | | |
| Pin badges | 11 00 | | |
| Electrotypes | 31 00 | | |
| Proceedings | 95 00 | | |
| Interest on deposit | 10 32— | 2,414 99 | |
| | | | $2,958 48 |

Disbursements:

| | | |
|---|---|---|
| J. A. Goodrich, Treasurer's account 1903. | $7 17 | |
| W. M. Mackay, Secretary's account 1903. | 40 56 | |
| W. M. Mackay, Secretary's salary | 150 00 | |
| W. M. Mackay, Secretary's account | 486 47 | |
| W. Kent, editing 1903 Proceedings | 100 00 | |
| R. W. Ryan, reporting annual meeting | 179 50 | |
| J. J. Little, printing | 843 58 | |
| Schoen & Kellerman, printing | 164 40 | |
| Bormay & Co., cuts | 56 81 | |
| D. Williams Co., cuts | 17 75 | |
| Leonard & Satterlee, reporting summer meeting | 75 00 | |
| E. M. Bloomer, certificates | 28 50 | |
| Mechanical Engineers, rooms | 65 00 | |
| Cross & Begulin, pin badges | 51 00 | |
| Empire State Surety Co., Treasurer's Bond | 6 00 | |
| Stevenson & Masters, Treasurer's cash book | 1 05 | |
| Collections | 1 50— | $2,274 29 |
| Balance on hand | | $684 19 |

Respectfully submitted,

U. G. SCOLLAY,

Treasurer.

## REPORT OF BOARD OF GOVERNORS.

Gentlemen: Your Board of Governors met and organized January 21, 1904, appointing a Committee on Finance, Membership and Publication and an Executive Committee. The various committees have given careful attention to their duties, and the board has met as often as was found necessary during the year.

We are able to report an increase in membership, and the financial affairs of the Society are in good condition, with sufficient funds on hand to pay for the publication of the 1904 volume, which has just been corrected, and which will be forwarded to the members as early in the year as possible.

According to resolution at the last annual meeting, the Board of Governors met and revised such parts of the by-laws as were complained of at the last annual meeting, relative to the election of members and duties of officers, sending out a letter ballot to the members. Seventy votes were cast, sixty-nine being in favor of and one against the amendments, which were adopted.

A revision of the Constitution and By-laws, with a revised list of members to December 15, 1904, has just been published, and will be forwarded to the members this week.

A summer meeting was arranged for July 15 and 16, 1904, at Detroit, Mich., which proved successful in every way.

All the papers to be presented at this meeting, with the exception of one, which will be read from manuscript, have been printed and forwarded to the members.

ANDREW HARVEY, Chairman,
JOHN GORMLY, Vice-Chairman,
ROBERT C. CLARKSON,
H. D. CRANE,
R. C. CARPENTER,
C. B. J. SNYDER,
A. E. KENRICK,
J. J. BLACKMORE,
W. M. MACKAY, Secretary.

The President: The report will be received and placed on file.

Mr. B. H. Carpenter then read the report of the Committee on Compulsory Legislation, as follows:

## REPORT OF COMMITTEE ON COMPULSORY LEGISLATION.

*The American Society of Heating and Ventilating Engineers:*

Gentlemen: Your Committee on Legislation respectfully submits the following report of its work during the past year:

Mr. B. H. Carpenter, member of your Committee from Wilkesbarre, Pa., has made several efforts to have the matter taken up by the authorities of that State, but seems unable to make any headway unless the State Board of Health can be shown that it is for the best interests of the people at large to have a law for compulsory heating and ventilating public buildings placed upon the statute books.

The member from Chicago, Mr. T. J. Waters, has taken the matter up and has forwarded to the attorney of the Board of Education of that city the copy of the heating and ventilating bill which has become a law in this State, with the request that the subject be given due consideration at an early date to the end that a suitable bill may be presented to the Legislature, which is now in session, some time this winter. He is using his best efforts to obtain a favorable result.

As to the State of New York, I am pleased to report that the efforts of your Committee, backed by members of our Society, have been successful, with the result of placing on the statute books a law which provides for the compulsory heating and ventilating of public buildings in the State.

It was found to be useless, however, to attempt to force through the bill as originally drawn, and we at last resorted to making it an amendment to the Consolidated School Law, in which form it passed without opposition.

This may be a suggestion for members from other States which may prove of value to the Society.

We were materially assisted in our work at Albany by Superintendent of Public Schools C. W. Cole of that city, and by Associate City Superintendent Andrew W. Edson of the city of New York, who is President of the National Educational Association.

We would, therefore, respectfully suggest the adoption of the following resolution:

*Resolved,* That the sincere thanks of this Society be tendered to Superintendent of Public Schools C. W. Cole of Albany, N. Y.,

and Associate City Superintendent Andrew W. Edson, New York City, N. Y., for their valuable assistance in obtaining the passage of the compulsory heating and ventilation law for the State of New York through the Legislature of 1904.

Respectfully,

Committee on Legislation.

The President: The report of the Committee on Compulsory Legislation will be received and placed on file. The resolution included in the report will be attended to later.

Has the Committee on Standards any report?

Mr. Crane: We have nothing at all to report. There is quite a lot of work for the committee to do if it were brought officially before us. As it is, we haven't taken any matters into consideration.

The President: Thank you. Next is the Committee on Tests.

The report was deferred, the chairman of the committee not being present.

The President: I will appoint as tellers of election, Mr. John S. Brennan, Mr. L. B. Sherman and Mr. W. C. Vrooman. They will receive the votes. The polls will close at half-past three.

Secretary Mackay: About half-past eleven I received this cablegram, dated London, England:

"*To American Society of Heating and Ventilating Engineers, New York:*

"The English Institution assembled send greetings."

On motion, the cablegram was received and ordered to be entered upon the minutes, and the President was requested to send a suitable reply.

The President: Next in order is new business.

Mr. Cary: Mr. President and gentlemen, I wish to state that a committee has been formed, composed of officers of the four engineering societies, the American Society of Civil Engineers, Mechanical Engineers, Mining Engineers and Electrical Engineers, for the purpose of agreeing upon certain abbreviations to be used in their transactions. There has been a great confusion of abbreviations, some using one set of abbreviations and others using others. In order to overcome this trouble and get uniformity in the engineering literature of the country, the four societies

I have named appointed this committee, and they agreed upon a set of abbreviations to be used in their transactions.

Seeing they have taken action in this matter and have made a report, bearing date of March 11, 1904, I think we should also come up in line and have our transactions agree in abbreviations with the transactions of the other societies. I cannot say that I agree with every one of the abbreviations offered, but where I would take exceptions others would consider them "well taken." It is pretty hard to agree upon everything that somebody else has gotten up, but in the main they are satisfactory, and I would propose that we adopt them.

Mr. Chew: If the other people have adopted this thing we can follow along, but before we do it I think the Committee on Standards should give attention to it and make a recommendation at the last day of the meeting.

Mr. Barron: I move it be the sense of this meeting that the Committee on Standards recommend the abbreviations be adopted by this Society, with additions. (Carried.)

The President: If there is no further business, we will stand adjourned until eight o'clock to-night. (Adjourned.)

## SECOND SESSION, TUESDAY, JANUARY 17, 1905.

The meeting was called to order at 8.20 P.M. by President Harvey.

The President: The report of the Tellers will be the first thing in order.

Mr. Brennan presented the following report:

### REPORT OF THE TELLERS.

| | |
|---|---|
| Total votes cast | 115 |
| Defective votes thrown out | 1 |
| Blank votes cast | 1 |
| Votes thrown out for arrears in dues | 3 |
| Votes cast for William Kent for President | 75 |
| Votes cast for John Gormly for President | 35 |
| Votes cast for R. P. Bolton for Vice-President | 68 |
| Votes cast for H. L. Hall for Vice-President | 42 |
| Votes cast for C. B. J. Snyder for 2d Vice-President | 65 |
| Votes cast for J. J. Blackmore for 2d Vice-President | 45 |

| | |
|---|---|
| Votes cast for W. M. Mackay for Secretary.......... | 101 |
| Votes cast for H. A. Joslin for Secretary............ | 8 |
| Votes cast for U. G. Scollay for Treasurer.......... | 84 |
| Votes cast for F. P. Blodgett for Treasurer.......... | 24 |

Vote for Board of Governors as follows (first five elected):

| | |
|---|---|
| B. H. Carpenter.................... | 77 |
| B. F. Stangland.................... | 73 |
| Jas. Mackay........................ | 72 |
| A. B. Franklin..................... | 68 |
| J. C. F. Trachsel.................. | 56 |
| W. N. Haden........................ | 45 |
| C. R. Bishop....................... | 28 |
| Thos. Barwick...................... | 55 |
| Wm. H. McKeever.................... | 43 |
| H. A. Loeb......................... | 33 |

JOHN S. BRENNAN,
WM. C. VROOMAN,
L. B. SCHERMAN.

The President: You have heard the report of the Tellers.

Secretary Mackay announced the result.

The President: We will proceed to the "Topics": "The relative advantage of low pressure and vacuum systems for small work in residences." (No discussion.) The next question is No. 2: "The ventilation of tunnels, subways and kindred constructions." I believe Mr. Cary has something on that subject.

Mr. Cary then read the paper. Plans were distributed in explanation of the paper, and it was discussed by Messrs. England, Barwick, Wolfe and Crane.

Secretary Mackay: The proprietor of this hotel and his brother, who is the engineer, and who designed the apparatus, have suggested that if a sufficient number of the members are interested they will be glad to have them inspect their heating and power plant to-morrow morning, at any time they might arrange, say at eleven o'clock, or any time.

The President: I think you will find that a very interesting subject, gentlemen, and I am sure all those who can do so will be benefited by it.

Secretary Mackay moved to adjourn until to-morrow, Wednesday, January 18th, at 2 o'clock P.M. (Adjourned.)

THIRD SESSION, WEDNESDAY, JANUARY 18, 1905.

The meeting was called to order at 2.30 P.M. by President Harvey.

The President: Professor Carpenter will read his paper on "Investigation of accuracy of a direct reading hygrometer."

Professor Carpenter then read the paper. It was discussed by Messrs. Barron, Wolfe, Chew, Lyman, Brennan, Kitchen, Kent and Donnelly.

President Harvey: If there is no further discussion we will hear Mr. Chew read Mr. Thompson's paper, entitled, "Gas as a fuel for hot-air heating."

Mr. Thompson's paper was read, and discussed by Messrs. Chew, Harvey, Kent, R. C. Carpenter, Barron, Cary and Donnelly.

President Harvey: If there is no further discussion, we will proceed to Mr. Bolton's paper on "Steam heating in connection with condensing engines."

Mr. Bolton read a brief abstract of his printed paper. It was discussed by Messrs. Kent, Carpenter and Almirall.

President Harvey: If there is nothing further on this subject we will proceed to Topic No. 3: "Grate and heating surface and their relation to space and exposure in furnace heating."

The paper was discussed by Messrs. Chew, Kitchen, Oldacre, Kent, Lyman, O'Neill, Bolton, Armstrong and Barron.

Mr. Quay: I move a committee of three be appointed to investigate this question.

President Harvey: I think we have a Committee on Tests, Mr. Quay.

Mr. Quay: I think we had better have a special committee for this one thing. There seem to be no data after all our discussion. I think a special committee should be appointed to make a thorough investigation and report at the next meeting.

Mr. Kent: I second the motion, and wish to say the Committee on Tests is no good. I have been a member for some years, and we cannot do anything and won't do anything until we have the means to do it with. The committee Mr. Quay

suggests, I believe, is a committee for compiling information now existing. I think Mr. Chew would make a most able member of that committee. Let them get these data together, put them in some shape—let us know about the proportion of grate and heating surface, of flue area, cooling surface of houses, etc. Let us find out what we do know and put it in the shape of a paper. It would not involve any tests, but only such records as the Society can furnish.

President Harvey: You have heard Mr. Quay's motion, seconded by Mr. Kent, that a special committee be appointed to compile information in regard to furnace heating. All in favor say "Aye."

The motion was agreed to.

I will name as that committee Professor Kent, Mr. Chew and Mr. Oldacre. I would also suggest the committee call with them what other men they think will give them the greatest aid in working out the best results that they can get, and present the data at our next annual meeting.

Professor Kent: I accept that position, and I will ask the Society to appropriate enough money to send out circular letters to every member, asking for such information as they can send in, and we can then compile that information. Our committee can get together and frame a list of questions that ought to be asked in order to get the information.

President Harvey: It is in your hands now. Professor Kent is President for next year. It is up to him to look out for that. If there are no objections we will proceed to the last topic. It is Topic No. 4: "The requirements of heating boilers using bituminous coal."

The topic was discussed by Messrs. Cary, Crane, Barron, Capron and Shanklin.

Professor Carpenter moved the meeting adjourn until to-morrow, January 19, at 10.30 A.M. (Adjourned.)

## FOURTH SESSION, THURSDAY, JANUARY 19, 1905.

The meeting was called to order at 10.30 A.M. by President Harvey.

The President: We are a little behind time, but have been waiting for a quorum this morning. Mr. Mackay has a paper from

Mr. A. B. Reck, of Copenhagen, Denmark, "Experience with radiators in the top story of a building."

Secretary Mackay read the paper. It was discussed by Messrs. Chew, Quay, Barron, Kenrick, Brennan, Monroe, Mackay, Carpenter, Kent, Snow and Vrooman.

Secretary Mackay: As the members will recollect, this is an addition to the paper presented by Mr. Reck, at our last annual meeting, descriptive of his system. These are some troubles experienced in the application of it in a building in Chicago, which he thought, as a matter of record, should be included in the proceedings of the Society, and which would strengthen his paper.

Professor Carpenter: I move that Mr. Reck be requested to give a more detailed account of this particular case.

Seconded by Mr. Kenrick.

The motion was agreed to.

President Harvey: The next paper on the programme is entitled "The circulation of hot water," by Mr. John S. Brennan.

Mr. Brennan read the paper. It was discussed by Messrs. Cary, Mackay and Kent.

The President: If there are no objections, I think a motion to adjourn until afternoon would be in order. It is now after one o'clock.

Secretary Mackay moved to adjourn, which was duly seconded and agreed to, and the convention adjourned to meet at 2.30 P.M.

## FIFTH SESSION, THURSDAY, JANUARY 19, 1905.

The meeting was called to order at 2.30 P.M. by President Harvey.

The President: We will now proceed to the discussion of Topic No. 6: "Methods of heating large bodies of water for public baths and industrial purposes, by steam or otherwise."

The topic was discussed by Messrs. Blackmore and Kenrick.

The President: We will now listen to a paper on "European methods of heating fifty years back," by R. C. Carpenter.

Professor Carpenter then read the paper. It was discussed by Messrs. Barron and Mackay.

Secretary Mackay: The Committee on Tests was not in a position, on account of the Chairman not being present, to make a report the first session. Professor Carpenter, the Chairman,

is here now, and I understand has a report to present. I move we return to the head of Committee on Tests.

The motion was agreed to.

### REPORT OF THE COMMITTEE ON TESTS.

Professor Carpenter: The Committee on Tests has had such meetings as were possible during the time of the sessions, and I am simply presenting something to the Society which will serve as an excuse for the existence of the committee. After I have read the paper, I wish to make a few remarks concerning what I think should be done with the committee.

Professor Carpenter then read the paper, entitled "Test of a steam-heating boiler."

Professor Carpenter: In regard to the Committee on Tests, the committee has found it difficult to devote any time to making tests. I think that this is the first attempt to present any data of any kind for the Society through this committee. I have commenced work, on two different times, which, I believe, if it had been carried to a conclusion would have given some valuable results, but other work has prevented the finishing of those investigations. It seems to me that such a condition of affairs is likely to continue, and that the committee is likely to be of very little benefit to the Society as an investigating committee. It strikes me that every individual member of this Society should feel it his duty, if he gets hold of valuable scientific data, to present them to the Society, and, consequently, that every member might consider himself a member-at-large of such committee. In such a case there would be no particular use of the committee except to classify and arrange such data. I feel, as the result of past experience, that the committee is one which is likely to do the Society no good, simply because the men who compose it do not have the time to carry on testing work, and the Society does not have the means which could be used in this way. I believe fully as much could be accomplished if the committee were done away with. (Applause.)

Mr. Chew: I agree with what Professor Carpenter has said as regards the difficulties of the committee, being composed of men living in different places, working together on any specific piece of work or any big work. If we have a Committee on Tests, there is a place for a record of the work any individual may do, and which Professor Carpenter suggests be turned into

the Society, to be filed. Then the Committee on Tests can tabulate from whatever may be submitted something of benefit to the Society. To discharge the committee no doubt would be gratifying to the members of it. I do not think the Society has any right to find any fault with the fact that they have accomplished very little. The committee can be continued and the Society can entertain the same feelings of generosity towards them as in the past. Then the Society can take up the Professor's idea of working as a committee of the whole and reporting to a central head. I would recommend, instead of discharging the committee, that the committee be authorized to send through the Secretary to the members, with some of the papers he sends out from time to time, a vote or some other thing, a specially prepared letter or blank. The Committee on Tests can formulate a series of questions that they would like to know about, heating high buildings by means of hot water, for instance, the two-pipe system, overhead or under feed, etc. I think if the Committee on Tests works in that way that we probably can gather together data that the Committee on Tests would like to have. I am afraid if we discharge the committee we will have nothing. We have had Professor Carpenter's report, and our Proceedings will show that something has been done. There is something in our Proceedings to show we have had a committee, and if we discharge that committee I doubt very much if the same results will show in future Proceedings. I strongly favor the continuance of the committee, and make the suggestion that the committee formulates questions in reference to different kinds of work, to be sent to the members.

Secretary Mackay: I agree with what Mr. Chew says, but see one possible objection—not on account of the work—but we took a vote of this Society on the metric system some time ago, also voted on amendments to the by-laws and things of that sort, something of vital interest to every member of this or any other engineering society, and less than one-third of our membership voted on the questions; whether they were too busy or what, I do not know. We don't seem to be able to get our members to give an expression of opinion. We don't get a majority—not one-third, either through press of business, lack of inclination, or something of that sort. We might go to a good deal of trouble trying to get certain things, which we would not get judging from past results.

Mr. Oldacre: I wish to make a motion, that a question box be constituted as a feature of this Society under about the following ideas, as near as I can get at it. That any questions that may arise during the course of the year be sent to the Secretary, and let those questions be sent out not less than thirty days prior to this meeting, in printed form, so that every member can have an opportunity to study the questions. Let these questions be read before the meeting, so it will give a chance for everybody to discuss them.

Mr. Barron: I want to impress upon the membership this fact —take the report on this boiler which has been described. To do the work properly, the boiler should be down in full plan, details specified, the names of the parties making the test, and everybody concerned or interested. Every man examining the paper should apply the personal equation. But we cannot do it. We simply can do the best we can, and it is impossible, for commercial and other reasons, to do more. This is not a commercial body. We are technical, and if we get into the commercial line the allegation will be made against us that we are a commercial trade society. All we can do is the best we can in the direction stated by Professor Carpenter, and the membership ought to appreciate it.

Mr. Quay: There are two points. One, I understand the committee is a standing committee under the Constitution, and that being the case, we cannot wipe it out. The other point is, I don't presume it is necessary to keep the same members on the committee year after year. It might be well to add some new members to that committee.

Another point is, I think the work of any society is handled better by committee than in a general way, and I think it would be better for each committee to handle their business—write their own letters and attend to their own correspondence, rather than do it through the secretary. For this reason: communications from the secretary of any society become somewhat formal. Members are used to receiving them.

Mr. Chew: I differ with Mr. Quay about the mode of procedure. The trouble has been the committees don't get together, and, consequently, cannot work. They are widely separated. They could, by correspondence, ask for information on given lines. When the committee, by correspondence amongst them-

selves, have formulated a blank, it can be printed by the Secretary at a small cost, and in that way you can get information on lots of things.

In regard to Mr. Oldacre's suggestion of a question box, if we maintain in the Secretary's office a question box, as he suggests, a man can ask questions and the Board of Governors when they sit can see these questions. The answers will be filed with the Secretary later.

The President: Before putting that motion, I think if you will just write it out in as definite shape as possible it can go before the meeting in proper shape.

Professor Kent: I move the question be referred to the Board of Governors.

Motion seconded.

Secretary Mackay: He makes it arbitrary to do certain things which are governed by our Constitution and By-laws. We cannot publish anything the Publication Committee will not endorse, and, as a result, nothing can go before the Society unless endorsed by them.

The President: It is moved that the matter be referred to the Board of Governors, with power to use their discretion in the matter.

The motion was agreed to.

Mr. Jellett: We all listened to Mr. Snyder last night and noted what he had to say in regard to the services of Albert A. Wray and Loyal L. Davis, in connection with the bill recently passed by the Legislature of New York State. I think that this Society ought to show its appreciation of work done, and I would like to move that the Board be instructed by this meeting to prepare and have engrossed a set of resolutions embracing the sentiments of this Society, and thanks to the Hon. Albert A. Wray, of New York, and Hon. Loyal L. Davis, of Glens Falls, N. Y., in recognition of their services. Professor Cole, of Albany, also had a great deal to do with that work, and I think it would be well for the Society to extend to Professor Cole their appreciation of his services.

The motion was duly seconded.

The President: We can leave that to the Board to handle.

Mr. Quay: I would suggest to include the Superintendent of Schools—I do not know his name.

The President: I think we can trust the gentlemen who have that in charge, Mr. Quay.

The motion was agreed to.

### INSTALLATION OF OFFICERS.

The President: The next matter on the programme will be the installation of officers. You have elected Professor William Kent, of Syracuse, N. Y., as your President; Mr. R. P. Bolton, of New York, as First Vice-President; Mr. C. B. J. Snyder, of New York, as Second Vice-President; Mr. W. M. Mackay, New York, as Secretary; Mr. U. G. Scollay, Brooklyn, as Treasurer. If these gentlemen are here, they will please come forward. I would suggest that Professor Carpenter and Mr. Crane escort the newly elected President to the platform.

(President-elect Kent was escorted to the platform amid applause.)

The President: I place you in charge of the Society, and it gives me great pleasure to leave so valuable a man here.

Professor Kent: It gives me great pleasure to be the successor of so worthy a man as our past President.

(Professor Wm. Kent in the chair.)

The President: Will you, Mr. Secretary, give me the next business in order? What about the First Vice-President?

Secretary Mackay: Not present.

The President: You have elected five directors. I introduce Professor Carpenter as the only surviving member of the Board. I will ask the Secretary if it is possible to have a meeting of the Board this week.

Secretary: We can certainly get a majority of them.

The President: The next thing on the programme is Topics for Discussion.

The next is No. 5: "Advantage of low pressure hot-water heating systems with the velociy of circulation increased by force of vacuum." How is it possible to apply force of vacuum?

Mr. Chew: The question occupied much more space than is taken here. It comes from one of our French members, who presents in the question the words "emulsion" or "pulsion." When he says "emulsion," he means discharging steam into the pipe for increasing the temperature, not so much to drive it

along, but to increase the temperature and force circulation in that way. If it is possible to give any information that will be a help to him, I think he is entitled to it.

Secretary Mackay: M. Debesson, one of our Paris members, suggested the topic. It was arranged that one of our new French members should read a paper descriptive of hot-water circulation, and it was in reply to a letter stating the paper would not be ready that this topic came up.

The President: I wish some one would put in a written discussion of the subject. I think there is a feeling that the efficiency of hot-water system would be improved if you had some economic means of forcing the water other than mere circulation caused by gravity.

Mr. Quay: Regarding the Reck's system being tested in this country, there was no report, but at the next meeting I have no doubt we will get some very clear information in regard to this system. I think we will have it at the next meeting.

Topic No. 6: "Methods of heating large bodies of water for public baths, etc., by steam," was discussed by Mr. Cary.

The President: The next Topic is No. 7: "The efficiency and durability of internally fired boilers, Scotch marine type, with Morrison furnace, compared with horizontal tubular boilers, for ordinary power plants at 100 pounds pressure."

Secretary Mackay: That question was suggested by a gentleman from Chicago, who has been here at all sessions, but is not here now.

The President: Isn't this outside of heating and ventilating?

Mr. Cary: I do not see how this applies to the subject of heating and ventilating. It seems an irrelevant question. There isn't much to be discussed.

Mr. Quay: I presume we are going outside our lines, and this subject is not strictly a heating and ventilating subject. It would be interesting, however, to hear some information on the subject.

The President: We had better rule this topic out as not germane to the work of the Society.

The President: The next Topic is No. 8: "Methods of improving the Society's records of the practice prevailing in different systems of heating." No. 10: "The extension of the work of the Society in special fields." No. 12: "The attitude of engineers to the Society." I am informed these are all ques-

tions relating to the general good of the Society, and are not technical. Topics 9 and 11 are technical. No. 9: "Proportion of grate surface required for different fuels." Has any one anything to say on the proportion of grate surface required for different fuels?

Topic No. 9 was discussed by Mr. Cary.

Topics No. 10 and 11 were discussed by Mr. Barron.

Topic No. 12 was discussed by Messrs. Chew, Childs, Mackay, Quay and Barron.

Topic No. 11: "The increased efficiency of heating apparatus using a fan" was then discussed by Mr. Quay and Professor Carpenter.

The President: I am asked to extend an invitation to the members of the Society to go to East Orange, N. J., to see a new combustion apparatus by Dr. Kitchen. He has placed pamphlets on the table, and any one interested can get them. The pamphlet is entitled "Scientific consideration of the subjects of saving fuel in heating and power production by improvement in the combustion process and by the conservation of the heating apparatus through its more effective transmission and working media."

It is getting near the time when we should adjourn.

I have to announce the committees for the next year. After consultation with several members, it has been decided to change the membership somewhat of standing committees. I will announce the following names:

*Compulsory Legislation:* Andrew Harvey, Chairman; C. B. J. Snyder, S. A. Jellett, T. J. Waters, B. H. Carpenter.

*Committee on Standards:* J. J. Blackmore, H. D. Crane, J. H. Kinealy, W. F. Wolfe, H. J. Barron.

*Committee on Tests:* Wm. G. Snow, Chairman; A. A. Cary, R. C. Carpenter, J. A. Almirall, H. H. Ritter.

Mr. Barron: I want to ask the privilege of having one of our members, Mr. Feldman, present a paragraph or two from a pamphlet he has on "Humidity." I think it could be included with the topical discussions.

Mr. Feldman presented the paper.

After a brief discussion the meeting adjourned.

List of members and guests present at the Eleventh Annual Meeting, January 17, 18, 19, 1905.

## MEMBERS.

Adams, Henry
Almirall, Juan A.
Andrus, Newell P.
Anness, H. L.
Barron, Hugh J.
Barwick, Thomas
Bernhard, John B.
Bishop, Chas. R.
Blackmore, J. J.
Blodgett, Frank P.
Brennan, John S.
Capron, Edmund F.
Carpenter, B. H.
Carpenter, Prof. R. C.
Carpenter, R. R. M.
Cary, A. A.
Chew, Frank K.
Clark, Geo. W.
Crane, H. D.
Cryer, A. A.
Davis, James H.
Doherty, Henry L.
Donnelly, Jas. A.
Downey, Wm. K.
Driscoll, Wm. H.
Dwyer, Frank A.
Edgar, A. C.
England, Geo. B.
Faulkner, Harry C.
Febrey, E. J.
Feldman, A. M.
Galloup, John O.
Gause, Bernard
Geiger, Aug.
Gombers, Henry B.
Goodrich, J. A.
Graham, Joseph
Hankin, Richard
Harvey, Andrew
Joslin, H. A.
Jellett, S. A.
Kenrick, Alfred E.
Kent, Prof. Wm.
Klemm, J. George, Jr.
Lyman, C. M.
Mackay, Wm. M.
Mallory, H. C.
McCann, Frank G.
McKiever, Wm. H.
Munroe, Edwards K.
Nowell, H. W.
O'Hanlon, George
Oldacre, C. E.
Osbourn, Millard P.
Payne, John A.
Quay, D. M.
Ritter, H. H.
Scollay, U. G.
Shanklin, John R.
Sherman, L. B.
Slotboom, C. M.
Smith, H. A.
Snow, Wm. G.
Snyder, C. B. J.
Stangland, B. F.
Stock, Edw. L.
Teran, Cesar
Vrooman, Wm. C.
Webster, Warren
Wolfe, Wiltsie F.

## GUESTS.

Adams, H. C.
Andrews, Chas.
Armagnac, A. S.
Armstrong, Chas. G.
Austin, Wm. E.
Baker, Chas. H.
Baker, W.
Barnes, E. W.
Basshor, C. H.
Bowers, J. H.
Bowers, Walter
Bradt, Chas. D.
Brennan, G. P.
Burgomaster, Daniel
Burns, H. S.
Candy, C. H.
Carter, H. D.
Childs, R. F.
Conrow, R. W.
Draler, W. H.
Eddy, H. C.
Eden, L. E.
Edwards, J. Irving
Fairweather, F. H.
Fisher, F. W.
Fryer, John W.
Giveron, J. M.
Godfrey, Harold
Hancock, Louis W.
Hecht, H. F.
Hill, J. E.
Hopkins, R. D.
Huey, George
Jones, F. L.
Kitchen, J. M. W.
Landan, W. A.
Lyman, H. B.
Macon, W. W.
May, B. D.
Metz, Harry
McDonald, J. J.
McDuff, G. G.
Mills, Benj.
Morrel, Augustus
Morton, J. K.
Moses, P. R.
Mosner, W. A.
Nickerson, A. T., Jr.
O'Brien, John J.
Olmstead, E. J.
O'Neill, A. J.
Paradice, Chas.
Quay, D. M.
Robinson, A. F.
Schuetz, F. F.
Scott, C. E.
Singer, E. F.
Stevens, F. H.
Stoddard, A. B.
Sutton, Frank
Swinton, Benj. W.
Vaux, Fred J.
Ward, Thos. J.
Warren, J. T.
Winslow, E. D. F.

# PAPERS

OF THE

# ELEVENTH ANNUAL MEETING,

New York, January 17, 1905.

## CXXXV.

# INVESTIGATION OF ACCURACY OF A DIRECT-READING HYGROMETER

BY R. C. CARPENTER.

The following paper is devoted principally to the description and investigation of two direct-reading hygrometers of German make, which were sold by a Chicago store for less than $2.00 each. Both instruments are apparently alike and made by pasting some organic material, probably a piece of silk ribbon, on the inside of a spring coiled in the form of a flat spiral and very similar to a watch-spring in appearance. This spring is fastened at its center to a fixed post and is connected near its free end to a light pointer. When the organic material absorbs moisture from the atmosphere it winds more closely about the center and deflects the pointer over a grad-


FIG. 1.—DIRECT-READING HYGROMETER.

uated scale in one direction, while if the air becomes dryer the moisture is evaporated from the organic substance and the spring carries the pointer in the opposite direction.

The graduations at one end of the scale correspond to full saturation, which is marked 100, and on the other end of the scale to absolutely dry which is marked 0. The form of the dial of the instrument is shown in the accompanying diagram. Figure 1 and a perspective view in the half-tone form a photograph, Figure 2.

The instrument is neatly mounted in a nickel case and would certainly be of great convenience to heating and venti-

lating engineers provided its indications would prove accurate and uniform. Even if the instrument should not be accurate, it would prove of value if the readings remained constant for the same conditions and could be corrected by adding or subtracting a uniform amount or by multiplying or dividing by a constant number.

It is quite reasonably certain that the amount of moisture which exists in the air plays an important part in the comfort of people who are occupying heated rooms. While it is not definitely proved, it is doubtless practically true that if a room be very dry the temperature must be maintained considerably higher in order to make the occupants comfortable than if the air of the room contained a moderate amount of

FIG. 2.—PHOTOGRAPH OF DIRECT-READING HYGROMETER.

moisture, say 50 to 60 per cent. of that required for saturation.

Instruments for measuring the amount of moisture in the air are called either hygrometers or psychrometers. There is no particular reason for using either the one term or the other, but in order to prevent confusion between the two types of apparatus referred to in this paper the term hygrometer will be used in reference to the direct-reading instrument which has just been described, while the term psychrometer will be used when referring to the dry and wet bulb instrument which in the investigations referred to was arranged so that it could be whirled in the air. The latter was used as a standard of comparison in the tests to be described.

Direct-reading hygrometers are old inventions. I find several described in a work on Physics* which I have, which was printed in 1771, as being at that time old. The construction as described in the old book referred to is as follows: "The moisture and dryness of the air are shown by the hygrometer which is made in several ways, but that with a cord is most common and useful; that by shrinking with moisture will turn an index one way, and extending with dryness will turn it the contrary way over the graduated limb of a circle. It would be endless to take notice of all the methods that have been attempted by philosophers and most of them without success. However, some are better than others and will endure for a considerable time very well. I shall here give an account of one which is the best of any I have hereto thought of. It is made of a string, either of hemp or catgut, and shows the increase in moisture of the air by its twisting and shortening, and the dryness by untwisting and lengthening."

Saussure, in 1783, constructed a hygrometer in which he used a fine horsehair about 20 inches long, which he freed from grease by soaking in a weak solution of sodium carbonate and then washing. This is often spoken of as the hair hygrometer, one form of which is shown in Figure 3. When the hair takes up moisture from the atmosphere it increases in length, and when it gives up moisture it shortens. This property of lengthening and shortening can be used to swing a lever or pointer over a graduated dial substantially as already described. Prof. W. Hempel, in his work on "Gas Analysis," translated by Prof. L. M. Dennis, states that such a hygrometer is very satisfactory for many purposes: It is generally constructed of the form shown in Figure 3. A. D. Hall, in his work on "Heat," states that a better instrument may be made by using, instead of horsehair, whipcord that had been soaked in sea salt or in a solution of salt containing a little hygroscopic magnesium chloride. This causes the whipcord to absorb moisture and lengthen by untwisting when there is an increase of water vapor in the air and shorten for the reverse condition.

You are, I think, all familiar with the hygrometer sold as a

* "Philosophia Britannica," by B. Martin. Third edition, Volume II., London, 1771.

toy which is actuated by the twisting or untwisting of a bit of catgut so as to bring the figure of a man to the door of a little cottage when the air is near saturation, and the figure of a woman when the air is dry. Paper flowers soaked in a solution of cobalt salt will appear red in a moist atmosphere and blue in a dry atmosphere, and may be used as hygroscopes for roughly showing the moisture contents of the air.

The instrument commonly employed by the Weather Bureau* for the determination of the amount of moisture in the

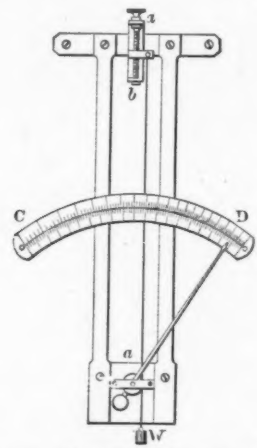



FIG. 3.—THE HAIR HYGROMETER.

air consists of a metallic frame constructed so that it can be whirled through the air and supporting two similar thermometers placed side by side and so arranged that the bulb of one is kept constantly wet and the other dry, and both are exposed freely to the air. This instrument was used at first in a stationary position, the wet bulb being kept moist by wicking which covered the bulb and extended into a cup of water beneath, the water rising by capillary action. An extended use proved the necessity of whirling the instrument rapidly in order to bring the wet bulb in intimate contact with the air which is necessary for accurate determinations.

* "Psychrometric Tables," by C. F. Marvin. Weather Bulletin, No. 235, Washington, D. C., price 10 cents.

It is recommended that the wet bulb be covered with fine muslin, which is fastened with strong threads so as to fit smoothly over the bulb, and is wet by inserting the covered bulb in a cup or open-mouthed bottle which is fitted with pure, or if possible distilled, water, which should be practically at the temperature of the air. In order to obtain a reading with this instrument it is whirled or swung rapidly through the air for fifteen or twenty seconds, with a twisting motion of the

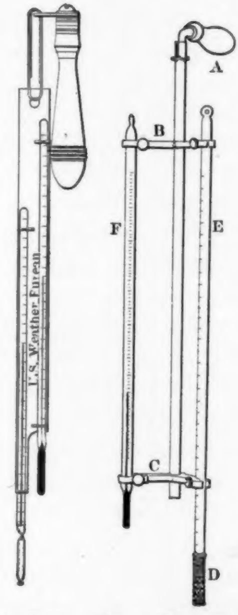



FIG. 4.—SLING PSYCHROMETER. FIG. 5.—PHOTOGRAPH OF SLING PSYCHROMETER.

hand. It is then stopped and the wet-bulb thermometer read; the operation is then repeated three or four times or until the reading of the wet-bulb thermometer is at a minimum. This instrument, as shown in Figure 4, is now employed as a stand ard by the United States Weather Bureau. The one used in our experiments is shown in Figure 5, and differs simply in the form of the frame used. Accurate tables have been constructed from experimental data for reducing the thermom-

eter readings so as to show percentages of saturation.* The principle on which this instrument acts is due to the fact that as long as the air is not saturated, water will evaporate at the surface of the wet bulb, heat will consequently be withdrawn from the bulb and the temperature which the wet-bulb thermometer indicates will be less than that indicated by the dry-bulb thermometer. The difference of reading of the two thermometers will be proportional to the rapidity of evaporation, which is in turn a function of the relative humidity, so that the dryer the air the greater is the difference between the readings of the two thermometers. No rational or theoretical law has been found connecting the readings of the wet and dry-bulb thermometers with either the dew-point or the percentage of moisture required for saturation. The results must be interpreted by reference to an experimental formula or a table which has been based upon experiments made by comparing the readings of the thermometers of the dry and wet-bulb instrument with hygrometers of other types.

Another form of hygrometer was devised by Daniell for the measurement of the "*dew-point*," which is the temperature at which the air becomes saturated with moisture. Daniell's hygrometer consisted of a small and delicate thermometer enclosed in a bulb, with a broad gilt band on the outside on which it is easy to observe the deposition of dew. The bulb is connected to a second bulb and the two bulbs and the connecting tube contain only ether and ether vapor. Ether is poured on the outside of the second bulb in such a manner as to cause a rapid evaporation from one bulb to the other and a lowering in temperature of the first bulb. The temperature at which the deposition of dew takes place is the temperature of the dew-point for the given conditions. This hygrometer was greatly improved by Regnault, but although it may be made to give the dew-point accurately it is a difficult and clumsy apparatus to use and has been largely superseded by the one previously described.

The most accurate of all processes of determining the amount of water vapor in air is by passing a measured vol-

* See United States Weather Bulletin, No. 235, "Psychrometric Tables," price 10 cents; also "Heating and Ventilation," by R. C. Carpenter. New York: J. Wiley & Son.

ume of air through calcium chloride. The air being weighed before and after the experiment, the difference in weight shows the amount of moisture which it previously contained. Hempel in his work on "Gas Analysis" describes an accurate and quick method of determining the percentage of moisture by measuring the volume before and after the water vapor has been absorbed.

The last three methods can hardly be used by heating and ventilating engineers since they require apparatus and trained observers, which can only be found in a completely equipped laboratory. The sling psychrometer is a portable instrument, but its use requires some dexterity and considerable time. The data obtained with this instrument are reduced only by consulting tables which are given in my work on "Heating and Ventilation" and by the Weather Bureau.

The object of the experiments to which reference has been made was to determine first, whether there was any direct relation between the readings of a direct-reading hygrometer of the first type and the sling psychrometer, and also to determine whether or not the errors of the direct-reading hygrometer remained essentially constant.

The experiments referred to were all made by taking simultaneous readings on the psychrometer and on the direct-reading hygrometer and comparing the results. Two direct-reading hygrometers were tested. These are referred to in the report as A and B. Hygrometer A was first tested in March, 1904; it was also tested in December of the same year. The results of the two tests are not quite in harmony, but the difference is so small that it may be accounted for by the personal errors in the readings of the psychrometers, so that it is probable that there has been no change of importance during the first year of use. The slight discrepancy noted may also be due to the fact that the psychrometer is a difficult instrument to read accurately and variations in the moisture conditions of the air in different parts of the room take place so rapidly and are frequently so serious as to cause considerable discrepancies in results obtained by different observers. I am satisfied that the results with the psychrometer depend a good deal upon the skill of the observer and the method of manipulation of the instrument.

The average of the results of the tests referred to indicate that Hygrometer A read too low by an amount which averaged very nearly two degrees, so that to correct the hygrometer reading with this instrument about two degrees should be added. Hygrometer B, on the other hand, reads high, an amount approximating five degrees. In the practical use of these direct-reading hygrometers they should be left in a horizontal position for some little time and read when in that position rather than when suspended from the ring with which the instrument is provided, being protected from moisture given off from the breath. The instruments are exceedingly sensitive to changes in moisture contents.

The general results of the investigation indicate that the direct-reading hygrometer can not be depended upon as an instrument of precision, but that it can be depended upon to give approximately the percentage of saturation when its error is known sufficiently accurate for the purposes of the heating and ventilating engineer. It is necessary, in every case, however, to find the error of the instrument, which may be done by comparing each instrument with the results obtained by use of a psychrometer of standard form, in order that the amount of error could be accurately determined and corrections made for the same when necessary.

In the investigations to which reference was made, the experiments were conducted through a wide range of temperatures and moisture contents. This was made possible by the use of a small building which was erected a year earlier for the purpose of noting the increase in temperature with a given radiation for external weather conditions. The experiments were also made with a wide range in moisture contents for each temperature. The individual observations are somewhat variable, but the results of the comparisons obtained by three independent observers* do not vary greatly. For very high temperatures the error of Hygrometer A changes from negative to positive.

The following table shows the average results of the cali-

* W. M. Wilson, M.E., February, 1894; R. P. Schoenijahn, December, 1894; E. Hall Faile, December, 1894.

bration for different temperatures, as made by the independent observers referred to:

| Observer A. | | | Observer B. | | |
|---|---|---|---|---|---|
| Range of Temperature. Deg. Fahr. | Hygrometer reads high deg. of saturation. | Hygrometer reads low deg. of saturation. | Range of Temperature. Deg. Fahr. | Hygrometer reads high deg. of saturation. | Hygrometer reads low deg. of saturation. |
| 58 to 70 | 0 | 0.3 | 55 to 70 | .... | 0.5 |
| 71 to 90 | .... | 3.5 | 70 to 80 | .... | 1.5 |
| .......... | .... | .... | 80 to 100 | .... | 2.5 |
| 91 to 110 | .... | 4.0 | 100 to 110 | .... | 2.3 |
| 110 to 130 | 3.6 | .... | 110 to 120 | 1.1 | .... |
| .......... | .... | .... | 120 to 130 | 6.5 | .... |

The errors with an instrument of this class are not great for the ordinary conditions of temperature and moisture content, and it will serve a very useful purpose in all living apartments, showing at a glance the approximate condition of the atmosphere of the room with respect to moisture.

The following short table is compiled from the extensive table published in U. S. Weather Bulletin 235, Washington, 1900. It is useful in reducing the readings of the wet and dry bulb psychrometer:

RELATIVE HUMIDITY OF THE AIR.

| Difference of Temperature, Wet and Dry Bulb. | Temperature of the Air. | | |
|---|---|---|---|
| | 32° F. | 70° F. | 90° F. |
| 0.5 | 95 | 98 | 98 |
| 1 | 89 | 95 | 96 |
| 2 | 84 | 90 | 92 |
| 3 | 69 | 88 | 89 |
| 4 | 59 | 81 | 85 |
| 5 | 50 | 77 | 81 |
| 6 | 39 | 72 | 78 |
| 7 | 30 | 68 | 74 |
| 8 | 20 | 64 | 71 |
| 9 | 11 | 59 | 68 |
| 10 | 2 | 55 | 65 |
| 12 | .... | 48 | 58 |
| 14 | .... | 40 | 52 |
| 16 | .... | 33 | 47 |
| 18 | .... | 25 | 41 |
| 20 | .... | 19 | 36 |
| 22 | .... | 12 | 31 |
| 24 | .... | 6 | 26 |

The following table is useful in computing the weight of moisture entertained by the air. It gives the weights in pounds which 1,000 cubic feet of air is capable of absorbing:

## MOISTURE ABSORBED BY AIR.

The quantity of water which air is capable of absorbing to the point of maximum saturation in pounds per 1,000 cubic feet at various temperatures.

| Degrees Fahr. | Pounds in 1,000 cu. ft. | Degrees Fahr. | Pounds in 1,000 cu. ft. |
|---|---|---|---|
| —20 | .0313 | 55 | .6927 |
| —10 | .0510 | 57 | .7414 |
| — 5 | .0643 | 60 | .8206 |
| 0 | .0806 | 62 | .8774 |
| 5 | .1007 | 65 | .9689 |
| 10 | .1247 | 67 | 1.0344 |
| 15 | .1536 | 70 | 1.1400 |
| 20 | .1887 | 72 | 1.2154 |
| 25 | .2301 | 75 | 1.3366 |
| 30 | .2797 | 77 | 1.4230 |
| 32 | .3019 | 80 | 1.5619 |
| 35 | .3380 | 85 | 1.8194 |
| 40 | .4070 | 90 | 2.1130 |
| 45 | .4877 | 95 | 2.4463 |
| 50 | .5823 | 100 | 2.8237 |
| 52 | .6246 | 105 | 3.2501 |

## DISCUSSION.

Professor Carpenter: The question may be raised in the minds of a good many as to the necessity of such a paper before a gathering of heating and ventilating engineers. The paper has a bearing on the method of determining the amount of moisture in a room. I was led to investigate several instruments manufactured for measuring moisture in a room, and this paper gives the results of the investigation.

My conclusions are that this simple instrument is one which will show, with a fair degree of accuracy, the moisture contents of a room. It may be in error 2 per cent. to 5 per cent., but it will show approximately the amount of moisture in the air. I think it is a very useful instrument. The cost is small, and I believe it would be well worth while for most mechanical engineers to have one. I might add that I have been investigating the moisture contents of the air in my house during the past two months with an instrument of this kind. The house is heated with steam heat, and is perhaps a fair average representative of any steam-heated house. I find that the moisture contents, expressed in percentage of saturation, run from about 8 per cent. to 35 per cent., and that a good deal of the time it stands at about 25 per cent. Out of doors at the same time I found the per cent. of moisture to be 60 per cent. to 70 per cent., so that the air in my house is extremely dry, dryer than the air, I think, you will find in most deserts.

Mr. Barron: I want to ask Professor Carpenter what he finds is the percentage of moisture on the average outside his house and the percentage inside—what are the relations?

Professor Carpenter: That question is, perhaps, difficult to answer accurately. I have made a number of observations outside, and I think have never found a time when the moisture was less than 60 per cent., and sometimes almost up to saturation—I think once or twice I found it nearly 100 per cent. I should estimate the average during the winter time to be, in our locality, taking the past month as a basis, approximately 80 per cent.

Mr. Barron: What is the percentage inside your house?

Professor Carpenter: At the same time it would not run higher than 25 per cent., and often drops to 15 per cent. and lower.

Mr. Barron: You live on high ground?

Professor Carpenter: Yes, sir.

Mr. Wolfe: These tables (referring to those mentioned in the report), as I understand you, were taken from Government reports?

Professor Carpenter: Yes, sir.

Mr. Wolfe: Ordinarily, people reading the hygrometer forget the matter of temperature. Of course we know that air at 100 degrees will carry more water than at 70 degrees.

Professor Carpenter: It is interesting to note that scientific tables showing the relations of temperature saturation of the air and the amount of moisture absorbed by the air are to-day entirely different from tables published ten years ago. I think the United States Weather Bureau has published different tables. I know the tables in use at present differ from those used a few years ago. The numbers in the table are not deduced by calculation, but depend on actual experiments. I think the table given here is the best authority we have at the present time as to the percentage of water held in the air at different temperatures. The table at the bottom of page 41 shows the relative per cent. of saturation for different readings of the dry and wet bulb thermometer. Table 10, at the back, shows how much water is held when the air is saturated at different temperatures. It shows, for instance, that one thousand cubic feet of air will hold, when heated to a temperature of 100 degrees, pretty nearly three pounds, and also that when the same amount of air is 20 below

zero it only holds .03 of a pound, an exceedingly small amount.

Mr. Barron: Can you give us some general averages of the moisture in the air, ordinary average through the whole winter, whether it isn't about 50 per cent. of the outside air, and whether the average home throughout the country gets down to about 25 per cent.? If we can get general truths like that they will be of some value to us. Most of our truths are general averages.

Professor Carpenter: I do not know that I could give any figures that would be very accurate. I think it is not greatly in error to say that during the winter months the percentage of saturation of out-door air doesn't run far over 70 per cent. in our locality. In summer, not quite so high. I think it is pretty fair to assume that in the house 25 per cent. is not far from the average. The percentage of moisture in outside air varies greatly in different localities.

Mr. Barron: You observed the temperature in the house where the dryness was about 22 per cent. to 25 per cent.?

Professor Carpenter: The temperature in the house is about 70 all the time, possibly varying from 68 to 72 degrees. It is quite probable—I do not say this as a fact—that if we run our moisture up to 60 per cent. we can run our comfortable temperature down eight or ten degrees.

Mr. Barron: I want to get another word from the Professor. From his general statement he led me to believe if we get increased moisture in our houses of 60 per cent. of saturation that we can reduce the average temperature from what it is fixed at now, about 70 degrees, to about 60 degrees. I would like him to go into that a little further for us, if he will do so.

Professor Carpenter: I do not have at present exact or accurate data, but there are a good many reasons for believing that if the air of a room could be made more moist we would require less temperature. If the air were more moist the evaporation from the skin would take place at a much less rapid rate, and as that process is a cooling or chilling process, we must naturally have a higher temperature in order to counteract it and in order that the room may be comfortable.

It is also known that in some countries, for instance, those of Continental Europe, 59 degrees Fahr. is a comfortable temperature. The only way we can reconcile that practice with

ours is by assuming that more moisture is found in their homes.

I have had some experience with natural gas. I have learned that at one time in some portions of the country it was cheaper to let it burn constantly than to use muscle enough to turn it off, and as a result in rooms temperatures were allowed at times to get high. Such rooms were very dry, and the people living in them wanted the temperature something like 75 to 80 degrees or else they felt uncomfortable. In the extremely dry air produced by the constant heat they felt chilly unless the air was at a very high temperature. These things are but relative, and I am not sure that they are of any value whatever.

Mr. Barron: General statements are not of any scientific value, but they are of value in this way—they get the general drift of men's minds. If we can learn in our practice that we can reduce the temperature or the heat of a building by increasing the moisture, equalizing it with the moisture outside, it would be a valuable general truth. While it is not a specific truth or a scientific truth, yet it would be a general fact for us to know, and in order to get it in men's minds, if it is a fact, is why I am trying to get the Professor to explain.

Mr. Chew: I would like to hear from some hot-air furnace men. Nobody has spoken from the furnace standpoint. I see Mr. Lyman sitting over yonder.

Mr. Lyman: I have experimented on this line, but the experiments were so crude as to furnish no real data. I had always felt that possibly, in the moister sections of our country, the drying out of the air might not be any serious disadvantage, but several articles published in the Journals recently have referred to keeping the water-pan full. It does seem as if the temperature of a room were more comfortable by about two degrees if there is a plentiful supply of moisture. I have felt sometimes that I would like to carry experiments far enough to be able to regulate the amount of moisture supply for varying weather conditions, but so far all I can say is that it seems it does not require quite so high a temperature for comfort if there is abundant moisture in the room.

Mr. Brennan: I made a few observations in my house. I have a furnace-heated house and have one of these hygrometers, and several times when the thermometer in the house registered 80 degrees it was not uncomfortable. I had the water-pan, but

the hygrometer showed very dry. I would use considerable water by putting the pans in the different registers, and would use, possibly, in ten hours, fifteen gallons of water, and I found by using that water that the house was comfortable at 68 degrees —more so than at 80 degrees when I didn't use water.

Mr. Chew: Can Mr. Brennan give any idea of how the hygrometer read without the water-pan being filled afterward?

Mr. Brennan: It would change in five or ten minutes, sometimes. It seemed the air outside would change. The hygrometer in one hour would be very high, very dry, and after putting in the water, without doing anything, it seemed the air outside would change and the cold air come in through the furnace and change the hygrometer. It seemed almost impossible to keep that hygrometer down to where it was very moist. But by using the moisture, or taking a piece of cloth and saturating it and laying it over the pan in the register, it seemed to make more moisture in the air, and by running a lower temperature of heat, say 65 degrees to 68 degrees, the air felt comfortable, and you felt as if you were plenty warm enough.

Mr. Barron: I want to ask Mr. Wolfe if he knows of any experiment made where the moisture was increased in a room up to 90 per cent., or near the saturation point at 100 per cent., what the results were in heating the room, and if there was comfort with the lower temperature?

Mr. Wolfe: No; I do not.

Mr. Kitchen: What degree of saturation is the most healthful condition? I know from my own experience that moist, summer temperature gets disagreeable with a high saturation. I have a place in New Hampshire, where it is extremely dry, and we can live in comfort there in summer out-of-doors with the temperature at 60 degrees, whereas in East Orange, to be comfortable in the house we have to have about 75 degrees. We have a large lot of Jersey cattle there—rather delicate—with no special protection for them, and the temperature goes to 17 and 20 below zero. I think when the temperature was 17 below zero I could go out without hat and coat. But it was dry. In my own house I have steam heat and hot-air furnace. The hot-air furnace is small and simply dries the air to a certain degree—I don't know what it is, but I know when the air is comfortable. I think if the air is too dry it has an effect on the mucus membrane, nose

and throat, and perhaps the skin, but as a matter of fact the more moisture you have in the atmosphere the more you feel the vapor on the body. I think that is a general principle that can be accepted. I would like to know from the Professor if there are any data as to the best amount of saturation.

Professor Carpenter: This question is a little different from any of the others as to the effect due to dry or moist air. I do not know of anything very definite relating to the question. I have searched for information along that line with little satisfaction. This much is true: that dry air might for certain conditions or diseases be much more healthful than moist air. I haven't been talking about healthfulness in my discussion, but about "feeling comfortable." It seems, however, fairly probable that a moderate degree of saturation is more comfortable, and also more healthful, than extreme dryness or extreme dampness. We know extreme dampness is not healthy in all cases. But, on the other hand, we know certain diseases require extremely dry air in order to be properly treated; so the question of health is very complicated. When the weather decreases in temperature the moisture increases, and when the weather is warm the reverse is true. In our locality we are likely to have a good deal of moisture in the air in the spring and fall, and we have many bad colds. I feel certain that you will find a difference of opinion as to the healthfulness and unhealthfulness of dry or damp weather. It depends largely on the disease to be treated.

Professor Kent: I think there was a discussion of this subject at the last meeting, but the volume is not yet printed. I think it was shown in that discussion that there has been a change of opinion within the past few years in regard to that question. It used to be that all the furnace-heat men thought it necessary to have a water-pot in the furnace to make moist air. I know of a case where the hot-water pan used to get dry too frequently on account of being too near the furnace, and another water pan was placed immediately under one of the registers in the parlor, which was kept full of water, and in that the atmosphere was kept pretty well saturated. It was thought to avoid quick evaporation, one of the former troubles, but the windows were found to be coated with ice on account of too great evaporation in the room. In Syracuse I find the custom is not to have water-pots at all, and we don't notice any difference. We have an extremely

dry atmosphere there in the winter time; last winter it was 20 degrees below zero sometimes, and every one said that they didn't feel the cold twenty degrees below as the people in New York City did at zero.

Speaking of comfort, some years ago in Pittsburg, in the steel works, it was noticed in June when the thermometer got to 90 in the shade that the men were quitting work, and it was very hard to keep a full force of men. In September, with the temperature 102, not a man left. The atmosphere was very dry, and at 102 the men didn't suffer from the heat, but they suffered badly with the thermometer at 90 in June, with maximum humidity.

On the other hand, I know doctors treat some cases by keeping the air saturated with moisture, while for lung diseases the patients go to Arizona to get dry air.

Mr. Chew: The question has not been answered. We have in our office a horsehair hygrometer which says: "From zero to 45 is disadvantageous to men and animals; from 45 degrees to 70 degrees is normal." The atmosphere should have from 45 degrees to 70 degrees of humidity to be normal. These words are above it, which would lead you to suppose normal humidity was between 45 and 70 degrees. There is considerable variation. Indoor and outdoor conditions widely differ.

Mr. Blackmore: The discussion as far as it goes shows that we have gotten very few actual data as to what moisture is necessary for the air in a room to produce comfort. Opinions have been expressed that it would vary a great deal with different people. That is undoubtedly so. Mr. Chew throws a little light on the subject by stating that authorities have said that from 40 to 70 was the normal amount of moisture required. I speak of 40 to 70 per cent. of moisture, 100 per cent. being saturation, or 100 meaning the air is carrying all the moisture it can carry without precipitation. This is an engineering society, and it is one of its functions to determine these facts. I think the facts could be arrived at without much trouble.

Professor Kent said in his remarks that people were largely doing without the evaporating pan. I think his experience, and I know my own, will teach that what the public at large does is not a safe guide. I think we got accustomed to the vapor pan years ago, and we are now going to the other extreme in neglecting

a very vital factor in our comfort and health when we neglect to use these pans. The question is not a difficult one of solution. If each one of the members who are interested in the business when making an installation would make a few observations, they could very quickly find out when the people were most comfortable, and if they made observations at these times to find out what the percentage of moisture was in the rooms, we could quickly arrive at a definite percentage to suit most people.

There is another point overlooked. Professor Kent says they have weather in Syracuse below zero. It is a well-known fact that when the air is below zero its moisture is precipitated—it is ably to carry very little. The introduction of the air at that low temperature on a heated surface, such as a hot-air furnace, puts the air in a condition where it has an intense thirst for moisture. If the required moisture is not supplied at the furnace it will be taking it out of the occupants in the rooms or anything that has moisture. Any one sitting in such a room—no doubt every one of you have felt it at times—will feel a parched condition of the skin, will feel uncomfortable, and yet I doubt if any of us have thought seriously what was the cause of that condition. It is obvious to any one if we think carefully over it. It is due largely to lack of moisture in the air. Professor Kent says they think rather of the remedy than the cause. We don't want to run away with the idea that internal thirst is always indicative of dry air. I don't know that I can throw any more light on the subject than has been given, but I want to go on record as one feeling that we have not gotten all the data possible on the subject and that it is a duty the members owe to each other and to the Society that these facts should be brought out and put in such shape as to be understood.

Mr. Wolfe: I was in the heating and ventilating business commercially, and naturally when tests were to be made I wanted the conditions as nearly favorable to myself as I thought I could have them. I did not depend altogether upon the water pan. I used what might be called a water pan, but in addition used a cotton cloth—cheese cloth—suspended with lower end in the water, and, by capillary attraction, the cloth would be moistened, and estimating that with the humidity ranging from 60 to 65, and with the temperature at 70 degrees, results were entirely satisfactory in every way. I found with too many cloths the

humidity was too high, and worked upon the basis of 70 degrees temperature with the humidity from 60 to 65, assuming that the occupant would be under sixty years of age, because as they pass that and grow older more heat is required for comfort. These conditions seemed to be the best to work under to have the apparatus passed as being satisfactory.

Mr. Chew: In reference to water pans for furnaces, I was talking with several of what we would call expert furnace men recently; men doing the better class of work, who don't have to sell fifty or one hundred in a lot where price is a consideration and durability is absolutely lost sight of, but men who spend most of their time in selling to people who buy homes and can afford to pay the price of a good job. These men all complained of the fact that at the present time most of the furnace manufacturers are not laying sufficient stress on the value of the water pan in furnaces, neither are they furnishing them. As was said, a few years ago, the furnace water pan was carried to the extreme. In my time in the furnace business the order came from the office to ship the water pan with the furnace when it was ordered, not otherwise. That you can see would save a few thousands of pounds of pig-iron and quite a bit in moulders' wages in the course of a year. The men who put the furnaces in the house didn't object to the manufacturer, and the water pan has gone out of existence. It is a step in the wrong direction. Furnace work should not be completed without some means of moistening the air.

Mr. W. T. Donnelly: I want to add a word. There is a point that is often overlooked in this question of moisture. There is no question but what moisture exists in the air. We know it as moisture saturation generally, as has been spoken of. It also exists in the air in the form of suspended moisture or small particles of water. We speak of this condition of moisture in the atmosphere as mist. The change of the weather largely controls our feelings at any particular time. We have what we speak of as the March air, the September or October air. It may be the same temperature or same humidity for March as September, but the feeling is altogether different. You must take into consideration, if you are going to heat a building, all these conditions, and understand all of them, before you can hope to meet them with your apparatus.

Mr. Barron: I hope the Professor will answer a hypothetical question. If the outside moisture is 60 per cent. and the moisture in here is 30 per cent., by increasing the moisture to 60 per cent. could we reduce the temperature to 70 per cent. and have the same comfort?

Professor Carpenter: I think the temperature now is somewhat below 70 degrees and the moisture, I believe, about 25 per cent. I feel quite certain if the moisture contents could be increased the temperature could be reduced. A number of examples showing that such is the case have been given. If the moisture content is increased, the temperature can be lower a few degrees and still produce the same degree of comfort.

Mr. Wolfe: We know that is so. We know from our own experience in the summer when the thermometer is 90 degrees or 95 degrees, with the humidity at 90, we suffer. While, on the other hand, if the humidity is 65 and the temperature is 90 degrees or 95 degrees, we get along very well.

Mr. Barron: That has been demonstrated in Arizona.

## CXXXVI.

# GAS AS A FUEL FOR HOT-AIR HEATING.

BY R. S. THOMPSON.

For cleanliness, convenience of management and economy of labor, gas is the ideal fuel. I believe the day is not far distant when the householder would no more think of fitting his cellar with coal in order to supply his house with heat than he would of putting a slaughter house in his cellar in order to supply his family with meat.

So obvious are the advantages of gas as fuel that on the introduction of natural gas, most people in the gas regions who had hot-air furnaces made haste to have the grates taken out and gas-burners put in. They had their cellars cleaned up and their coal-bins taken away.

In a large proportion of cases, after a trial for a single season, they made equal haste in having the gas-burners taken out, the grates put back and their coal-bins fitted up again

So generally unsatisfactory was the result of the attempt to use natural gas in hot-air furnaces, that it became a generally accepted idea throughout the gas regions that gas was adapted only for use in stoves and was entirely unsuited to hot-air furnaces.

And yet there is no scientific reason why gas cannot be as successfully used in hot-air furnaces as in any other form of heating apparatus.

The difficulty arose from lack of proper consideration of the conditions requisite in using a new fuel. Furnace men were putting new wine into old bottles. The result was that the old bottles (furnaces) were spoiled and the new wine (natural gas) was wasted.

There is a wide difference between a gas fire and a coal fire, each developing the same number of heat units per minute.

With coal, there is a bulk of intensely heated carbon throw-

ing off radiant heat in great quantity, consequently the fire-box and combustion-chamber of the furnace become intensely heated by that radiant heat and a comparatively small amount of this highly heated surface will heat a large amount of air.

There is comparatively little radiation of heat from the pure blue flame produced by the perfect combustion of natural gas. The heat produced is principally contained in the gaseous products of combustion. Owing to the dilution of these products with the nitrogen from the air and with the excess air usually admitted, this temperature is not very high. One of the principal products of the combustion of gas is water in the form of steam, and this contains in latent form a large amount of heat.

In the combustion of one thousand cubic feet of natural gas there will be produced from eighty to one hundred pounds of water in the form of steam. This steam will contain from eighty to one hundred thousand B. T. U. as latent heat which cannot be utilized until the steam is condensed into water by lowering its temperature below 212 degrees.

The attempt to heat a building with steam, allowing the live steam to escape uncondensed into a chimney, would be no more extravagant or unscientific than the attempt to heat with gas while allowing the live steam produced by the combustion of the gas to escape uncondensed into the chimney.

In order to use gas successfully and economically in hot-air heating, the following points are necessary:

1. A burner which will secure combustion of all the gas which passes through it and will not permit the production of carbon monoxide, or as it is commonly called "carbonic oxide gas."

2. A sufficient amount of surface exposed to the products of combustion on one side and to air at a temperature very considerably below 212 degrees on the other, and so arranged that the products of combustion will be reduced to a temperature below 212 degrees before leaving the furnace.

3. A sufficient quantity of air passing through the furnace to take the heat from the products of combustion without itself becoming sufficiently heated to impair its power in extracting heat.

4. Provision for getting rid of the water of condensation We will consider these points in order.

*The Burner.*—There has been much unscientific talk on this subject. The heat is in the gas, not in the burner. If a burner secures the combustion of all the gas which passes through it without the production of carbon monoxide, it has done all that can be done. Talk about burners which burn large quantities of air is all nonsense. A cubic foot of gas in complete combustion combines with a fixed quantity of oxygen. This quantity can be neither increased nor decreased. If the quantity of air supplied is insufficient, part of the gas will be unburned. If the air is supplied in excess of requirement, the excess of air will not be used. If more air is mixed with the gas than required, combustion will be imperfect and part of the gas will be unburned.

A perfect gas flame is a clear blue and perfectly transparent. A white or yellow flame, or a milky-blue flame indicates imperfect combustion. Sometimes a gas flame seems blue, but by holding an object on the other side it will be found it is not transparent. This indicates imperfect combustion.

If the flame "blows" or "lifts" away from the burner it shows too much air and consequently imperfect combustion.

If the fire "streaks up" in long, ragged flames, there is imperfect combustion.

If any portion of the burned gas mixes with the fresh gas, it poisons the latter and there is imperfect combustion, for a small amount of carbon dioxide mixed with gas renders the whole mixture incombustible.

The best gas fire is obtained by a large number of small jets so arranged that each jet will be fed with pure air and that the burned gas from one jet cannot become mixed with the fresh gas issuing from another.

A gas fire should have a supply of air in addition to that which is supplied through the mixer. It is impossible to supply enough air through the mixer to secure complete combustion, and one of the most common errors in setting gas-burners is the attempt to exclude all other air.

On the other hand if an excess of air is supplied it will unduly reduce the temperature of the products of combustion.

It is a mistake to attempt to "hold the heat back," by tightly closing the damper in the smoke-pipe. When this is too tightly closed the poisonous products of combustion are retained too long in the furnace and poison the fresh gas issuing from the burner. The way to avoid loss of heat to the chimney is to take the heat out of the products of combustion and then let them escape freely. When the heat has been extracted the sooner they are carried away the better. By actual test, with careful measurement of the heat units utilized in the air, I have found that more heat units were utilized with a free outlet to the chimney than with the damper tightly closed. In the latter case the smoke-pipe was cooler, but the total number of heat units developed per thousand feet of gas was less, showing that much of the gas was unburned.

Considerable scientific knowledge, skill and common sense are required to properly adjust a burner and mixer so as to secure the proper mixture of gas and air and the proper pressure in the burner. A three-quarter inch mixer will, in some burners, carry in more air than an inch and a half mixer in others. No rule can be given. I have secured a perfect fire with a three-quarter inch mixer, using one hundred feet of gas an hour, and I have had other cases where not more than fifty feet of gas an hour could be burned with an inch and a quarter mixer. A burner adjusted for one locality may not work properly in another as the composition of the gas and the pressure in the mains differ. The supply pipes should be of liberal dimensions, especially if long, as the friction in the pipes will reduce the pressure, and a low pressure at the mixer means an imperfect mixture of gas and air, and, in consequence, imperfect combustion.

*The Surface.*—It is impossible to give any hard and fast rule in regard to the amount of heating surface required, as there is much difference in the efficiency of surfaces, and so much depends on the quantity and temperature of the air carried over these surfaces. The problem is to extract the heat from the products of combustion, and no amount of surface will do this unless that surface is exposed to a constant current of air at a temperature considerably below 212 degrees. In general I have found that, with a liberal air supply,

there should be about one square foot of surface for each cubic foot of gas burned per hour.

*Air Supply.*—This is not so difficult to estimate. Natural gas is a product of uncertain chemical composition, and this statement is even more true in regard to most artificial gas, but a good quality of natural gas should contain about one thousand B.T.U. to the cubic foot. This would heat about five hundred and fifty cubic feet of air one hundred degrees. It would therefore appear that the amount of air passed over the heated surfaces should be from three hundred to five hundred cubic feet for each cubic foot of gas consumed. The greater the amount of air and the lower its temperature when passing over the heated surfaces the more complete will be the exhaustion of the heat.

This raises an interesting question as to what disposition should be made of this air after it is delivered to the room which I will consider later.

*Disposing of Water of Condensation.*—This is one of the most difficult problems in connection with the use of gas as fuel. A thousand cubic feet of gas weighs about thirty-seven pounds, and if of high quality contains from nine to eleven pounds of hydrogen, but as each pound of hydrogen in the gas combines during combustion with eight pounds of oxygen from the air there is a production of nine pounds of water for each pound of hydrogen contained in the gas, and a thousand cubic feet of good gas will produce from eighty to one hundred pounds of water when burned. To allow this water to escape in the form of steam at a high temperature, involves, as already shown, a great waste of heat. To utilize this heat by cooling the products of combustion to the point where the steam will be condensed, involves the problem of disposing of the water of condensation,

By proper construction of the burner and regulation of the air supplied to the fire, a large portion of this water can be mechanically carried off through the chimney in the form of mist which is suspended in the air after the latent heat has been removed, but some of it will, under some conditions, form into drops, run down the inside of the chimney and drop from the furnace.

Therefore every chimney used for a gas fire should be

perfectly straight and lined with tile, and provided with an opening at the bottom for the escape of the water.

In several cases I have provided for a gas furnace a special chimney made of gas pipe from three to six inches in diameter, according to the size of the furnace, with an inch and a quarter pipe at the bottom connected with a drain.

The furnace itself should be provided with some small openings to drain off the water, though, of course, the arrangement of these will depend on the construction of the furnace. I have been called to "sick furnaces" where the trouble was that the lower flues had become completely filled with water. I was called to one case where the furnace was connected with the chimney by means of a smoke-pipe thirty-five feet long. This pipe near the chimney was close to a window. I found the trouble was due to a careless janitor who had left this window open and the pipe at this joint had become completely closed with ice.

Most natural gas contains sulphur, and this when burned in connection with hydrogen produces sulphuric acid. The water of condensation is, therefore, usually quite corrosive. It will eat the mortar out of chimneys, hence the necessity for lining them with tile. It will corrode iron, so the smoke-pipe should be of heavy iron and coated inside and out with some acid-resisting paint. It should be kept in mind that the products of combustion of natural gas are not corrosive while hot. Corrosion begins only when these are sufficiently cooled to cause condensation of the steam. The more perfect the operation of your furnace, the more trouble you will have with condensation. Complete absence of trouble from this source is usually an indication that the furnace is ineffective.

I referred to the problem of disposing of the large amount of air which, in using gas, is required to extract properly the heat from the products of combustion. With a furnace burning one hundred cubic feet of gas per hour this would require from thirty to fifty thousand cubic feet of air per hour. The large amount is preferable.

But a family of six persons would require for the most perfect ventilation but ten thousand eight hundred cubic feet of fresh air per hour, so if all this air that is poured into the

house is allowed to escape at a temperature of 70 degrees through the windows or drawn off by a ventilating stack, there will be an enormous waste of heat.

To my mind, there is but one proper solution of this problem. Return to the furnace all the air supplied in excess of the amount required for thorough ventilation.

This would require additional expense in the installation of the system. But any system of hot-air heating is defective which does not provide means for the exhaust of the waste air as well as means for the supply of warm air. A perfect system of hot-air heating should include double piping, that is to say, one set of pipes for the supply and another set of pipes for the exhaust.

## DISCUSSION.

Mr. Chew: This paper speaks of gas as a fuel for hot-air heating, and, while it applies to hot air, there are quite a number of boilers and other apparatus on the market that occasionally are used with natural gas, and if the thoughts brought out in this paper are kept in mind by those called upon to make that kind of apparatus work, they will surmount some difficulties heretofore a mystery to them. I think the paper is certainly a valuable one for the information it gives on combustion—the effect of too high and too low temperatures—in the heat that is wasted by not properly burning the fuel. That applies with equal force whether the fuel is wood, soft coal, coke or some other fuel.

Mr. McCann: I want to ask the gentleman who read the paper how is he going to separate the air for ventilation and the air for the recirculators?

Mr. Chew: I do not know that I care to father the scheme, but I do know that in the West, far more than here in the East, they circulate the air, depending almost entirely for ventilation on what will come in around the windows, under the doors, etc. That has been discussed by correspondents in our paper quite considerably. Some men hold there should be absolutely no circulation of the air. The "rotary system," as the circulation idea is called by some, is favored considerably in the West and Northwest, where the temperature goes to 40, and sometimes 60, degrees below zero.

So far as separating it, I don't think even the most pronounced

advocates of the system make any claim for that. It is not uncommon in this section of the country where the circulating system is used to restrict the outside supply and draw the supply from the inside of the building, and in that way you have enough air to fill all the hot-air pipes, but if there is not enough from the inside then it will come from the outside.

Mr. Kent: There is a good deal of room for consideration in this paper, and I want to hear it discussed more fully. I regret I never saw the paper before until just now, and haven't had time to read it. During the reading I found I was in entire accord with a great many statements made by the author. "A perfect system of hot-air heating should include double piping." This is so, one set of pipes for the supply and another for the exhaust. I think the system is similar to the Aylesworth system of Canada, described at one of our meetings some time ago, but I think the paper contains a great many assertions without any attempt at bringing proofs. I wish the author had given some proofs of some of his statements, for to my mind some of them are not quite accurate. I will see if I can find one or two. He says: "If more air is mixed with the gas than required, combustion will be imperfect and part of the gas unburned." I do not think that is strictly accurate. If you will try to burn gas with exactly the amount theoretically necessary, you will have imperfect combustion. It requires, usually, about 30, or 40, or 60 per cent. maybe, excess of air in order to insure perfect combustion, and if you go beyond that, and give 100 per cent. excess or even 200 per cent. excess, I think the combustion will still be perfect. I can scarcely imagine a condition in which excess of air will cause the production of carbon monoxide and make combustion imperfect, or refusing to burn the hydrogen and letting it pass off unburned.

"If any portion of the burned gas mixes with the fresh gas, it poisons the latter, and there is imperfect combustion, for a small amount of carbon dioxide mixed with gas renders the whole mixture incombustible." I think that is entirely wrong—that you can mix very large quantities of carbon dioxide gas with incoming air and have perfect combustion. Blast furnace gas contains about as much carbon dioxide as carbon monoxide gas, is thoroughly poisoned with nitrogen and with carbon dioxide,

and yet that gas is combustible, and is burned under blast furnace boilers and in heating ovens.

Professor Carpenter: I do not understand this quite as Mr. Kent does. I understand this paper to refer in a very brief way to some difficulties which are experienced in burning gas. I think he has exaggerated some of the troubles. I know that in burning natural gas, especially by an open flame, that it is exceedingly difficult to avoid smoke. We are likely to burn out the hydrogen first, leaving the carbon, which appears as black specks. I have had so little experience with successful gas burning I do not feel I can talk as an authority upon the subject, but I know there are such difficulties.

Mr. Kent: There is another statement: "There is comparatively little radiation of heat from the pure blue flame produced by the perfect combustion of natural gas." It is possible that is correct. That condition can be remedied by letting the blue flame heat to a white temperature a mass of fire brick. That method is used in Pittsburgh.

Mr. Chew: There are men who favor the fire brick idea to give an incandescent mass, while other men experiment right in the opposite direction. Mr. Thompson is one of the men who believe you will get better efficiency from gas consumed without the incandescent fuel. I give that as his point of view. What you say is true, a good many men have so experimented, but Mr. Thompson is working the other way, and believes the other way gives better efficiency. I do not know that he says so in his paper, but I know of the experiments he has conducted and the line of work he is on, from talks with him in Detroit last summer.

Mr. Blackmore: It is a matter of regret that this gentleman is not here to read this paper. There are many questions I would like to ask in connection with this paper about problems which he may have solved in his experience but which are not in this paper. It is a good paper, but there is one thing he doesn't deal with as clearly as he should. He speaks of combustion, yet does not state clearly the difference between combustion at the burner and necessary mixture before it reaches the burner. There are two functions mentioned. We all know if impure air, partially consumed air, is mixed with gas going into the burner it is impossible to get good combustion, yet a considerable portion of that may be bad without interfering with the combustion itself.

This point he doesn't bring out clearly in the burning of the gas. While my experience has not been extensive so far as gas burning is concerned, I have noticed the mixing of air with the gas is a very essential feature. I do not see myself how a larger proportion of air being admitted at the furnace itself—around the burner, and yet away from the mixer, would have any effect on combustion whatever.

President Harvey: There is one experiment I have tried with very good results. I was melting brass in a furnace with natural gas, and I took the waste heat from the furnace into a system of iron piping to heat the air before going into the gas mixer, and I found by actual test we could melt 100 pounds in 25 per cent. less time and with 33⅓ per cent. saving of gas. We used a power blower to supply the air. Before we were taking the air direct from the outside temperature and blowing it against the gas, and there was a certain amount of time taken before we could heat the furnace.

It is not so much a question of cool surface as it is the large proportion of unconsumed air escaping up the chimney. Any excess of air carried off with the gases would have a tendency to waste heat.

Mr. Chew: I think I can give Mr. Blackmore just a little bit of information as to the first question he raised—about the air in contact with the flame. It was quite a common custom in the early days of natural gas burners to cut a hole in a piece of sheet iron and put the burner pipe—the supply pipe—up through that. The piece of sheet iron was so near the shape of the fire box that it made it almost air-tight, and to make it still further air-tight sometimes they packed asbestos around the edge, so that the burner really was in a case. No pure air was there to support combustion on the outer edge. I think that is what Mr. Thompson is alluding to when he says there should be some air on the outside. Such an attempt was made in New York City to burn gas in a chamber, no air getting into it except through the mixer. The effect with four Bunsen burners all burning in the combustion chamber was that air would rush through one mixer so that the flame would leave that burner and all the others would burn better. I do not know that is the condition Mr. Thompson is speaking of, but I know this condition has arisen, and he may be trying to cover it in his paper.

Mr. Barron: The paper is an extremely valuable paper, but it is defective. He should have shown a furnace, and also radiators, and then the paper could be discussed properly and been of considerable value.

But gas heating is a very important subject, and we are apt to overlook it. Partly it is the fault of our organization. Today there are a large number of manufacturers engaged in making gas radiators and appliances for using gas, yet none are represented among us.

Mr. Cary: One of the simplest gas-heating apparatus to warm rooms has recently appeared on the market. It consists of the lower part of a hollow sphere made of sheet steel punctured with holes to admit air which mixes with the gas. The gas and air mixed together are then made to pass out of the interior through a number of very small holes arranged along the under side of this sphere. In operation, the burning gas covers the bottom and outside of the sphere with a blue flame. This continuous flame is in direct contact with the air. I have found this heater both economical and effective.

Concerning the apparatus described by Mr. Chew, which includes a number of Bunsen burners with their top ends placed in an enclosed chamber, we find his device is quite opposite in principle to the one I have just described. The air and the gas in his apparatus are combined within the Bunsen burners, and then this mixture rises into a chamber containing an insufficient supply of air, which air is necessary to complete combustion on the outside of the flame. Had sufficient air been admitted into the flame chamber, complete continuous combustion would have been supported at all of the burners.

I have had experience in burning natural gas under boilers, and its handling is in many ways similar to the requirements necessary for burning petroleum oil. I have had considerable experience with oil fuel in both boiler and metallurgical furnaces. With petroleum, in some cases we need an intense flame near the burner, while in other cases we require a long, extended flame running the entire length of a long chamber. By using air in the burner under high pressure, you can with the proper mixture of air and petroleum obtain an intense flame near the burner. By using air of a lower pressure in the burner you can obtain a longer flame, while by using steam in the burner you can obtain

combustion distributed over a much longer distance than when using air.

Mr. Bernhard: Isn't there serious objection to the heat spoken of? Wouldn't it burn the oxygen with the air?

Mr. Cary: I experimented with one burner last winter, and I found it was necessary to open the sash of a window slightly to allow the objectionable odor to escape, and to admit fresh air.

Mr. Wm. Donnelly: My experience has been with heating water by gas, and it is remarkable to what a degree this has developed. It is possible with a copper coil to burn twenty-four to twenty-six cubic feet of gas per hour and transfer between 70 to 75 per cent. of the heat of the gas to the water, and at the same time obtain such perfect combustion as almost to detect no odor from the combustion. No odor can be perceived by standing close to the burner where the products are discharged.

I am interested in this paper, particularly the point brought out relative to the air surrounding the burner from the outside. That is a necessary consideration. You must have a space of free air to burn the gas after it is mixed in the most careful way. The development of burners for gas cooking ranges has perhaps brought out that point very clearly. The practice is to have small holes and separate them to just such an extent the flame will be surrounded by free air. If the perforations are made close enough the flames come in contact with each other, and then it is apparent the combustion is not as satisfactory nor as good.

It would seem, owing to the necessity of a large amount of surface when the heat of the gas is to be transmitted to the air, better to transmit the heat of the gas first to water and then distribute the same as for hot-water radiation, and if it is possible to extract so much of actual heat with such a small area of surface it would be found to be a very economical apparatus so far as the first cost is concerned.

# CXXXVII.

# STEAM-HEATING IN CONNECTION WITH CONDENSING ENGINES.

BY REGINALD PELHAM BOLTON.

Pressures in confined spaces at less than atmospheric density are very commonly classified in a general manner as a vacuum, a term which, of course, can correctly be applied only to a condition of absolute removal of the weight of the superincumbent atmosphere.

This condition is, of course, difficult to attain by commercial apparatus and within any extended system of chambers, receptacles and piping, but the condition of less complete vacua commonly applied to condensing engines does not appear to present radical difficulty in this respect.

In the economic operation of steam engines the condensation of the exhaust of low-pressure cylinders is a necessary factor, affecting the steam consumption to a substantial extent, and reducing the pressure of the exhaust steam-vapor to points considerably below the atmosphere, so that this exhaust has not been available for use in circulation through heating apparatus designed to operate at or above atmospheric pressure.

Steam vapor of pressures below the atmosphere is, however, used and operated successfully by what is commonly described as the "vacuum" system, an arrangement in which a pressure of steam less than that of the atmosphere is maintained in the interior of a sealed system of heating apparatus and circulated by ordinary methods.

The title above referred to is misleading. In point of fact such a system should be described as a "variable low-pressure" system, for, operated as it is without mechanical apparatus for the extraction of the contained air, the interior of the heating apparatus must first be filled with steam to such pressure above that of the atmosphere as will exclude the air contained in the system, through some form of non-return valve, after which the contained steam may be allowed

to condense to a certain extent, thereby producing a fall in pressure within the apparatus to the desired point of operation, the supply being then continued so as to maintain this lower pressure. In other words, a boiler and heating apparatus, all joints and connections being maintained sufficiently air-tight, is made a sealed system in which at some point of pressure, below that of the atmosphere, vapor is boiled from water, from which the air has been extracted, circulated to the radiators or coils, the condensation being returned to the boiler water-level by the common methods of gravity.

With such "variable low-pressure" systems a reduced fire will provide in moderate weather a vapor at a relatively lower temperature than steam at atmospheric pressure, whereby a correspondingly less rate of heat dissipation is afforded by the radiating surfaces.

Such a system is capable of considerable variation of pressure below the atmosphere, but it does not appear to offer relief from difficulties of sluggish removal of condensation unless operated by mechanical apparatus. The introduction of additional water to the boiler, as well as any inward leakage, involves the introduction of new supplies of air to the interior of the system, which can only be removed by again raising the initial pressure to some point above the atmosphere.

The conditions under which steam at pressures below that of the atmosphere exists differ in temperature, volume and in latent heat, not only as regards the vapor but as regards the products of its condensation.

In further pursuing the study of this subject, therefore, it may be useful to have these conditions stated in the following table:

TABLE I.

ELEMENTARY CONDITIONS OF STEAM AT AND BELOW THE PRESSURE OF THE ATMOSPHERE.

| Pressures in lbs. per square inch below the atmosphere | Atmospheric pressure. | 0.5 | 1 | 1.5 | 2 | 5 | 10 | 13.757 |
|---|---|---|---|---|---|---|---|---|
| Corresponding absolute pressure in lbs | 14.7 | 14.2 | 13.17 | 13.2 | 12.7 | 9.7 | 4.7 | .943 |
| Corresponding absolute pressure in inches of mercury | 29.92 | 28.9 | 27.88 | 26.86 | 25.85 | 19.748 | 9.566 | 1.92 |
| "Vacuum" below atmosphere inches of mercury | ............ | 1.018 | 2.04 | 3.054 | 4.07 | 10.177 | 20.854 | 28 |
| Temperature of the vapor, degrees | 212 | 210.28 | 208.49 | 206.64 | 204.73 | 191.73 | 159.54 | 100 |
| Heat units liberated by condensation | 967.7 | 966.9 | 968.1 | 969.4 | 970.8 | 980 | 1,002.6 | 1,044.4 |
| Cubic feet occupied by a lb. of vapor | 26.36 | 27.24 | 28.18 | 29.18 | 30.27 | 39 | 77.69 | 349.7 |
| Cubic feet occupied by a lb. of water of condensation | .01673 | .01672 | .0167 | .01669 | .01668 | .0165 | .01639 | .01612 |

As an example, steam generated (at normal atmospheric pressure with a barometric pressure of 29.9 inches, or 14.9 lbs.) from water at 212 degrees Fahrenheit, constitutes for each pound weight a volume of 27 2–10 cubic feet, or 47,000 cubic inches. A pound of water at this temperature occupies a space of only 29 cubic inches, therefore the steam fills a space 1,620 times greater.

At a reduction of one-half of the barometric pressure (to say 15.29 inches of mercury, or $7\frac{1}{2}$ pounds per square inch above absolute vacuum) the same pound of water occupies a relatively less space, or 28.56 cubic inches. But the steam vapor into which it is convertible at that pressure will occupy an enormously increased space of 50.8 cubic feet, or 86,745 cubic inches, a little more than 3,000 times the volume of the water.

It must further be borne in mind in order to fully comprehend the conditions of low-tension vapors discharged into enclosed spaces, that if water of saturation or condensation at a given temperature and pressure be present and be admitted to another space where a lesser temperature and pressure exists, the contained heat in that water renders it superheated for the new conditions and it will proceed to liberate this superfluous heat in the vaporization of a part of its volume.

To illustrate this, suppose a one-pound weight of heated water at 212 degrees, under atmospheric pressure of 14.7 pounds, to be admitted into a closed receptacle in which the pressure is only $7\frac{1}{2}$ pounds, the corresponding temperature of which is only 180 degrees, there is then a surplus of heat to the extent of 57 heat units which will go into the formation of steam vapor. To form steam vapor at that reduced temperature requires 987.8 heat units for each pound, therefore the 57 heat units will form $\frac{57}{987.8} = .057$ of a pound weight of vapor, and as a pound of such vapor will occupy 59.6 cubic feet, the result will be 2.8 cubic feet of steam vapor given off by the water.

The foregoing elementary characteristics make it evident that in an entirely closed system water may be evaporated to steam vapor by a less amount of heat as the pressure is lowered. But the steam vapor so formed is of a less tem-

perature and capable therefore of doing less work, and therefore such a method is one in which less work is done by less fuel. In other words it exhibits no economic advantage. But while this may be the case with a system in which fuel is consumed directly for the purpose of raising the temperature of a means of heat supply, it is an entirely different economic proposition if the wasted heat of a condensing engine could be made the source of heat supply and the "variable" feature of air exclusion can be dispensed with by the use of its already existing condenser and air-pump.

The subject, therefore, opens up the wide and interesting question of the use of exhaust steam from condensing engines, a matter fraught with great importance.

If it be possible to utilize for heating purposes the waste steam of a condensing engine, while still maintaining an economical degree of vacuum and thus retaining the working capacity of the cylinder, an economic result would be attained during the winter season which would advance the combined apparatus enormously in the utilization of the heat value of its fuel supply.

When it is remembered that of the heat in the fuel the actual heat value of the work done on the pistons of an engine is sometimes less than a tenth, the bulk of the remainder going off in the waste steam, or in the heat imparted to the condensed water, it is realizable how much is already accomplished by the use of exhaust steam from non-condensing engines in heating work, and how much more could be expected if the ideal condition could be attained of fully utilizing that waste steam for heating purposes after it has been used on the pistons down to pressures far below the atmospheric pressure, or, in other words, after its full economic work has been accomplished in a condensing engine.

In 1896 the Institution of Civil Engineers appointed a committee to consider and report upon the definition of a standard of thermal efficiency for steam engines.

Their report, published two years later, took the best recorded work of fire-grates, economizers, boilers, engines and condensers, and plotted an idealized combination. The following diagram, Fig. 1, is deduced therefrom for the sake of simplicity to a primary basis of one million units, and

shows that such an ideal combination of the boiler, with its chimney draft, grate, economizer and return feed, might be expected to deliver to the engine in the form of steam 968,330 units out of a total of 1,000,000 utilized upon the grate, a little under 97 per cent. (the best approach to which in actual practice is probably not more than 85 per cent.).

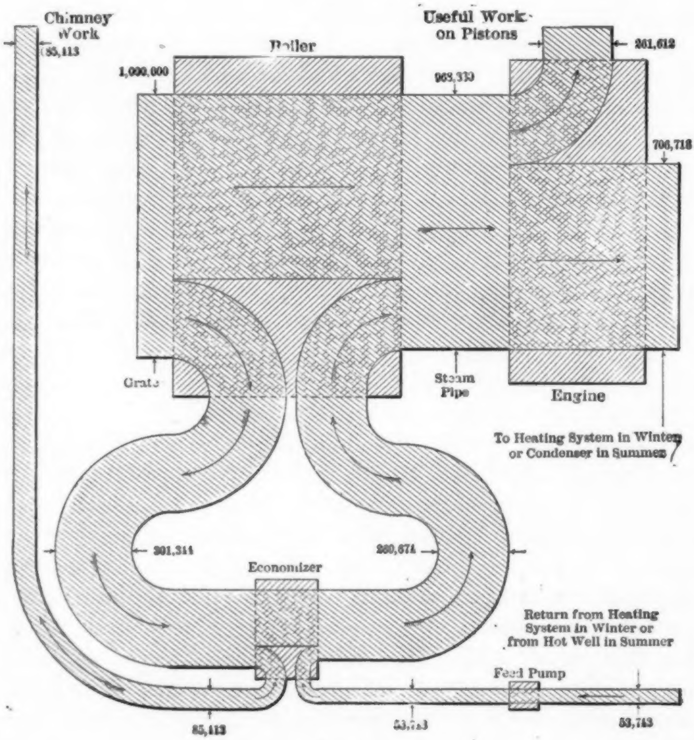



FIG. 1.

Of this 968,330 units in its steam supply, the work of the ideal engine utilizes as work on its pistons only 261,612, or say 26 per cent. of the original unit (in actual practice not more than 17 per cent.), part of which is due to the work of condensation, in which the balance of 706,718 units is entirely absorbed, except what is returnable as feed water, say 53,743 units, leaving a gross loss of 652,975 or 65 per cent. of the

original basis, which has departed with the cooling medium or condensing water.

The utilization therefore of this large proportion, in any economic manner, is a subject affecting the total ideal economy to a much greater extent than any improvement applied to any other part of the combined apparatus.

That this proportion is not excessive may be further judged from the comparison of its final result with those of any well-authenticated tests of combined steam-raising and utilizing apparatus, of which one may be here recited, having been carried out by myself upon the combined plant of the Ridgewood North Engine house, at the East New York Pumping Station, Brooklyn, for the Department of Water Supply.

The result, with internally fired boilers and triple-expansion high-duty condensing engines, showed in the actual heat value of the work in the water delivered into the reservoir from 8.8 per cent. to 11 per cent. of the heat value of the fuel.

It may here be observed that certain economic appliances of the nature of primary heaters on the exhaust of the L. P. Cylinders, and the use of open heaters receiving the feed-water and mingling it with drops and perhaps with some live steam borrowed from the intermediate receiver, also careful arrangements of steam jacketing and intermediate reheating may favorably affect such results and with them approach more closely to the ideal of the report. These elements, however, were largely present in the test referred to above.

The mention of the use of primary heaters upon the exhaust outlet of condensing engines fitly introduces here a reference to the system of hot-water heating by the use of heaters placed in such relation to the cylinders, which is known as the "Evans exhaust hot-water heating system with forced circulation." In this interesting apparatus, which has been applied to condensing engines, water, used as the heating medium, is forcibly circulated in the heating system, passing through a primary heater around or through which the exhaust of the low-pressure cylinder passes on its way to the condenser. The heat work extracted from the waste steam is limited of course to the temperatures of the vapor emitted

by the cylinders dependent upon the extent of "vacuum" carried.

In the course of a series of tests made by the writer for the Department of Water Supply, Borough of Brooklyn, last summer, at which tests Professor Rolla C. Carpenter presided as referee, a record of the actual work obtained from such a primary heater was secured and afforded interesting results, on account of the accuracy with which measurements of the surrounding conductors were enabled to be made.

The pumping engine was a Worthington Duplex horizontal triple-expansion jacketed type, having reheaters fed through the jackets, and being furnished with a primary heater having 60 square feet of brass tube surface in the L. P. exhaust close up under the point of emission.

Following are the temperatures obtained on various quantities of water through the heater, with the corresponding amount of steam, the gauge readings on the condenser, which was some 20 feet away from the heater, and the corresponding degree of vacuum extending into the cylinder as ascertained by diagrams.

TABLE II.

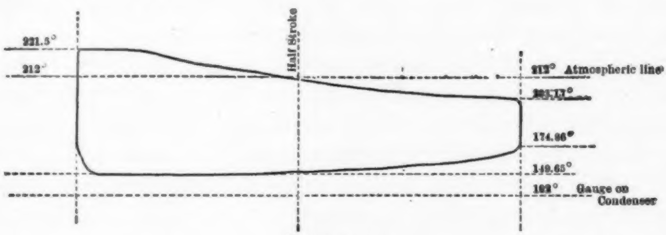
WORK OF A PRIMARY HEATER ON EXHAUST OF A WORTHINGTON CONDENSING ENGINE, MILBURN, L. I. 1904.

| | TIME. | Vacuum Gauge on Condenser. | Lowest Temperature in Cylinder by Card. | Steam Passed per Minute through Heater. | Water Passed through Heater per Min. | Incoming Temperature. | Outgoing Temperature. | Increase of Temperature. |
|---|---|---|---|---|---|---|---|---|
| | *A.M.* | *In. Mer'y.* | *Deg. Fah.* | *Lbs. Weight.* | *Lbs.* | *Deg. Fah.* | *Deg. Fah.* | *Deg. Fah.* |
| Test at Varying Quantities | 9.35 | 27.8 | 149.65 | ............ | 17.44 | 66.5 | 118.5 | 52 |
| | 9.40 | 27.8 | 149.65 | 53.12 | 12.4 | 66.5 | 119.5 | 53 |
| | 9.45 | 27.8 | 149.65 | 50.12 | 11.59 | 66.5 | 120.5 | 54 |
| | 9.50 | 27.8 | 149.65 | 53.62 | 11.59 | 67 | 121 | 54 |
| | 9.55 | 27.8 | 149.65 | 53.62 | 11.59 | 67 | 121 | 54 |
| | 10. | 27.9 | 149.65 | 51.62 | 11.59 | 67 | 121.2 | 54.2 |
| | 10.05 | 27.9 | 149.65 | 61.28 | 7.8 | 67 | 122 | 55 |
| | 10.10 | 27.9 | 149.65 | 54.12 | 4.98 | 68 | 126 | 58 |
| | 10.15 | 27.9 | 149.65 | 61.28 | 2.49 | 67.5 | 124 | 56.5 |
| | 10.20 | 27.9 | 149.65 | 59.28 | .162 | 68 | 126 | 58 |
| Aver. during 24 hrs....... | ...... | 27.9 | 149.65 | 54 | 3.44 | 67 | 115 | 48 |

It will be observed that the temperature imparted to the water is higher than the corresponding temperature of the degree of vacuum carried in the condenser, and that this is due to the higher temperature of the point of release, which is shown in the accompanying diagram taken from one of the L. P. cylinders.

We have in the foregoing a definite measure of the possibilities of heat extraction from the exhaust of a condensing engine under a given degree of vacuum. The interesting question will remain to what extent an increase in the pressure and temperature may justify a loss in the degree of vacuum, or in other words, how far will an increase of back pressure, with its effect in reduction of the engine's work, be recouped in the work of the heating system.

This will of course vary under the many varying conditions of work and cost of fuel and will form a further interesting study for the heating engineer.




SCALE 12.

FIG. 2.—DIAGRAM OF LOW-PRESSURE CYLINDER, WORTHINGTON DUPLEX TRIPLE-EXPANSION ENGINE, MILBURN, L. I. 1904.

The Evans system has shown at the Miami Light, Heat and Power Plant the following recent and interesting results kindly afforded to me:

| 1904. October 12 to 22 Inclusive. | | 1904. October 23 to November 22 Inclusive. | |
|---|---|---|---|
| Average temperature of weather... | 51.7 deg. F. | Average temperature of weather... | 45.33 deg. F. |
| Average degree of vacuum at condensers.................... | 21.74 in. | Average degree of vacuum at condensers.................... | 20.82 in. |
| Average temperature imparted to the heating water........... | 138.5 deg. | Average temperature imparted to the heating water........... | 148.8 deg. |
| Average increase of temperature imparted to the water in passing through the heater......... | 3.8 deg. | Average increase of temperature imparted to the water in passing through the heater......... | 4.24 deg. |

The effect upon the engine of raising the temperature of the heating medium is illustrated by the record of some days when conditions of matter varied largely.

| Date. | Outside Average Temperature. | Temperature of Water. | Vacuum. |
|---|---|---|---|
| November 4............ | 51.1 degrees | 131.5 degrees. | 22.52 inches. |
| " 8............ | 43.7 " | 141.1 " | 19.19 " |
| " 11............ | 32.2 " | 144.3 " | 18.75 " |
| " 14............ | 31.6 " | 153.2 " | 15.13 " |

The moderate temperature of the circulating water is represented as sufficing for heating purposes in moderate weather, and, when intenser conditions of cold weather are met, an auxiliary heater is brought into play supplied with live steam for the purpose. The temperature of the returning circulating water is somewhat raised and the primary heater then does less of the work of condensation, so that an addition must then be made to the work of the main condenser, or the degree of vacuum in the cylinder will be somewhat raised.

The results already attained show that this heated-water system possesses undoubted merit where a water apparatus is applicable, and seems to indicate a possible use of the waste steam direct for the same purpose, to which subject this paper directs attention in the hope that its development will attract the energy and ingenuity of the members of our Society and of heating engineers in general.

Such a combination is in point of fact already to be found to a certain degree in applications of the Webster system of circulation of exhaust steam, where the exhaust steam passed into a closed-heating system of apparatus, frequently circulated at a less pressure than that of the atmosphere, its products of condensation and contained air being removed by a vapor or "vacuum" pump.

In such case the heating system is acting as a partial condenser in similar manner to the primary heater, and the pump as the relief or vent to the superincumbent atmospheric pressure, in same relation as the main air-pump of a condensing system. The main condenser is absent, but in several instances the work of the pump has been desirably supplemented by an auxiliary surface-condenser or by a jet of water acting on the vapors given off by the condensed water, thereby assisting the operation of the pump, these approximating to the conditions of a condensing system.

These are the elements which would appear capable of development into a method of heating by steam vapors at low temperatures, and at those pressures below the atmosphere corresponding to usual economic practice with condensing engines.

The available temperatures are so low as to be sufficient

only for moderate weather, and the main question will be whether the necessary additional heat can be added to increase the temperature of the vapor when required. If it can, this source of heat supply, now generally wasted, may be largely utilized for heating purposes. Under what conditions this may be arranged, either as a "by-pass" or "shunt" from the line of travel of the steam vapor from the cylinder to the condenser, or by a direct passage of the whole volume through the heating system towards the condenser, will be a matter of study and experiment.

The second suggested method would appear to offer the best opportunity of solution.

The question of additional heat to be added to such a system would offer more difficulty than in the case of heated water, since the introduction into the system of a volume of live steam would tend to set up a back pressure more directly than by the raising of the temperature of circulating water. But the supply might be so arranged as to be directed into the radiating surface where its work would be done directly upon the covering surface and its heat, or the steam vapor may itself be superheated by the application of steam taken from the intermediate receiver or by live steam or heat of waste gases.

Such superheated steam need not then imply an increase in back pressure, if the superheated supply be actively drawn through the heating system by the action of the main condenser as proposed above.

## DISCUSSION.

Mr. Kent: It seems to me the scheme described in the paper has a chance of being introduced in practice, and I hope Mr. Bolton will go ahead and introduce it. It seems to offer great possibilities. We could have a condensing engine discharging steam into large low-pressure mains, with radiators of larger surface than are now used for high-pressure steam—say, the same amount of surface that we use for hot water—and carry the exhaust steam back into the tanks connected with a condenser in which is maintained a vacuum of such pressure as necessary, then as the water got cooler we could raise the pressure in the tank and the steam passing through would be of

higher temperature. If you wanted less steam for heating, we could shut off some of the exhaust steam, and instead of having it go through the pipes it could be shut off altogether. On the contrary, when the water was cool, we could open the vacuum and send through high-pressure steam. It seems a flexible system and one offering chances of economy. I think it is entirely practicable for factory heating, with an engineer in charge to look after the apparatus. It seems a very much cheaper plant in the first cost than the water-circulating system, and one which will offer as high economy as can be gotten out of any system whatever.

Mr. Carpenter: I think the system suggested by Mr. Bolton is practicable. One time I had opportunity to install a system on practically the same lines as suggested here. Instead of using a direct radiator I used an indirect, over which the air was forced for factory heating with a large fan. That system, unfortunately, at the present time has not been tested in this combination. It is also arranged that when the factory disposes of a certain non-condensing small engine now supplying exhaust steam for heating that the steam will be sucked through the indirect radiator by an air pump and the amount of vacuum produced will be regulated according to the degree of heat. We haven't had opportunity to test that yet, from the fact that the small engine is in use and supplies all the exhaust steam at present needed. I believe the system is practicable, for the reason that it does not seem unduly complicated, and I think it promises good results.

Mr. Barron: I want to ask Mr. Bolton, before closing this discussion, to explain this ideal system in a few words, if he will.

Mr. Bolton: The diagram is represented in the centre, not in dimensions but as a plotted area, representing the amount of heat units imparted to the boiler and produced by the fuel. Of that, of course, a certain amount has to go out in chimney work. In the case of the plant as shown here, the economizer diverts a portion and turns it back as hot feed water into the boiler—the lower curve on the righ-hand side. The wasted portion passes up the chimney and is shown as chimney work in the diagram. The chimney being a portion of the boiler, chimney work should not be regarded as lost, if the chimney is of an economical size and is not too large.

There is emitted from the boiler in the centre of the diagram

so much of the original area in the form of steam, and that as stated in the paper, under the best conditions, could not be more than 85 per cent., naturally, but theoretically and in a highly developed diagram it is brought out as high as 96 per cent.

You see next the work given out by the engine, the work done in the cylinder—not on the fly-wheel, but the piston, which is represented as passing upward on the right-hand side.

The remaining heat passes to the atmosphere or to a condenser. In the case of the condenser, there is by means of that steam a certain addition to the useful work, because the condenser is removing the back pressure on the piston, that is to be taken into account in the useful work done on the latter.

Finally you get the heat coming back in your feed. The whole system might be modified by introducing an open feed heater, in line between the feed pump and the economizer, and bring into it any drips, etc., from an actual system, thus increasing the amount returned to the boiler.

As regards the suggested method of applying this apparatus, the practical question is how far can you remove your condenser from your cylinder and still carry necessary degree of vacuum. There was in the case referred to in the paper about twenty to twenty-five feet between the cylinder and condenser of 10-inch pipe.

Such a heating system would of course have to operate at a very low temperature, and it must be, naturally, combined with some method of withdrawing the condensation in the heating system down to the condenser, and thence disposing of it by the usual air pump.

It is not my intention to throw cold water on the hot water circulating system, which is actually showing working results, but to suggest a study of the question whether it is not possible to do heating direct by the steam on its way to the condenser. That is a point, of course, which will have to be tested practically.

Mr. Almirall: I think we all know the importance of having the exhaust pipe between the condenser and the engine absolutely tight, and that the condenser also should be placed as close as possible to the engine. Anyone who is thoroughly familiar with the practical work of steam-fitting knows how difficult it is to have and the necessity of having the exhaust pipe on a condensing engine outfit absolutely tight in order to get a first-class

vaccum, and that the slightest air hole in such an exhaust pipe materially reduces the vacuum; and that very frequently these air holes will exist and interfere with the vacuum when they will not be indicated by the test of either steam or water.

In the system proposed it is intended to have an extended heating system act as a condenser, so that the steam would pass through all of the various coils, radiators and pipes before going to the condenser. In such a system, depending of course upon its size, there would be perhaps several thousand feet of pipe and doubtless hundreds of joints including valves, with stuffing boxes, glands, etc. It seems to the writer that it is almost self-evident that it would be an impossible matter to get an appreciable vacuum under those conditions and with the infinite possibilities of air leakage that would exist. It certainly would require an enormously large air pump to handle the amount of air and condensation, were it even feasible to obtain the vacuum.

With the system spoken of by Professor Carpenter it is possibly a different matter. In that system there was a fan with indirect coils, and the assumption is that this apparatus was placed fairly close to the operating engine, so that the exhaust pipe connection between the engine and these fan coils was short, and naturally the connection between the fan coils and condenser would be similarly short. It might have been and was, no doubt, possible to get a fair vacuum under those conditions with that particular system.

Being thoroughly conversant with the practical end of the pipe fitting business, it does not seem to me that the system suggested would be a practical one to put in operation.

Mr. Kent: I want to make a remark as to one thing said by Mr. Bolton, as regards the central condensing system. He says the proper place to put the condenser is right at the cylinder. I know of a big power plant not far from here where there is a central condensing system. Suppose an accident should happen to the steam pipe near the condensers, then the whole plant would be demoralized by throwing out all the condensers at once, while if the condensing plant was divided the explosion of a steam pipe would only throw out one portion of the condensing plant. I think there are reasons against the centralizing of the condensing system.

Mr. Barron: What percentage of the exhaust would reach the condenser?

Mr. Bolton: You will see my suggestions are tabled, and that there is a possibility of utilizing the whole of the steam. That would be a necessary question to be considered, the amount of heat obtained and the size of the engine. I imagine success could be attained, as the heating system is a portion of the condenser itself, and to that extent overcomes the difficulty that has been urged against it. I know it is difficult to keep a vacuum tight in a large system, and your condenser is added to overcome that difficulty. I do not know whether it is so, but I have often heard engineers say it is more difficult to keep 15 pounds from coming into a pipe system than it is to keep 100 pounds from going out.

## CXXXVIII.

# EXPERIENCE WITH RADIATORS IN THE TOP STORY OF A BUILDING

BY A. B. RECK, COPENHAGEN, DENMARK.

In discussing methods of computing radiator surfaces in proportion to heat-absorbing surfaces (windows, walls, ceilings, etc.), with American engineers, I have in some instances found that they employ rules which I think will give them too small radiators in the top story of a building, the rules not taking sufficiently into account the loss through the ceilings for that story. For this reason I have thought that it might be useful to mention that I have had to do with a case this winter where it has been necessary to increase the radiators in all the rooms of the top story in a building, although some allowance for the ceilings really had been made in the size of the radiators, only the allowance not being large enough, because I had understood there was an attic (unheated) over the story, whereas in reality there was not, the protection against loss of heat being only a ceiling of lath and plastering, an air space and the ordinary sheathing, roofing-felt and gravel on the roof timbers. The building of which I speak is one of the buildings in Chicago in which has been installed the Reck Hot-Water-Circulator System described in the paper I read before this Society in its meeting, January, 1904. In the building in question the radiators are distributed in 80 rooms on three floors and have a heat-emitting capacity of about 5,000 nominal square feet of hot-water heating surface. (Those of you who recollect my paper from last year will perhaps remember that what I call a "nominal" square foot is a square foot emitting 160 B. T. units an hour.)

The calculation of the radiators was based on 80 degrees difference between outside and inside, and for rooms with equal areas of walls and windows the radiators in the top story were given one nominal square foot more than the radiators on the floor below for every 18 square feet of exposed ceiling. This augmentation of the radiators on the top floor was based on

a rule employed by me for rooms with unheated attics over and the rule gave radiators on the top floor in many instances 33 per cent. larger than the radiator on the second floor in rooms with same areas of windows and walls.

Notwithstanding this the radiators on the top floor very soon proved to be insufficient to produce the same temperature as the radiators on the second floor, and the right temperature on the top floor was only attained by giving the radiators here one "nominal" square foot of area more than the radiators on the second floor for every 9 square foot of exposed ceiling, this being my rule for ceilings with no attics over, such as described in the beginning of my paper.

In the building referred to the radiators in many rooms on the top floor have now 66 per cent. more heating capacity than the radiators in rooms on the second floor with equal window and wall areas, without being larger than necessary. Seeing this I have thought it useful to direct your attention to this point that no rule for proportioning radiating surfaces will hold good for top floors unless some increase is given to the radiators here taking the areas and the construction of the exposed ceilings in consideration.

The cubical contents of the 80 rooms in the building are about 190,000 cu. ft., besides about 70,000 cu. ft. in heated corridors and staircases.

On each of the three floors are about 1,200 sq. ft. of glass surface in windows and doors and about 3,800 sq. ft. of net wall surface. In the 25 heated rooms on third floor are about 6,300 sq. ft. of ceiling.

It was assumed that the heat absorbed in the building would be with 80 degrees Fahr. difference between outside and inside:

| | | | |
|---|---|---|---|
| On first floor.... ............ | 1,200 sq. ft. glass × 80 = | 96,000 B.T.U. | |
| | 3,800 " wall × 18.4 = | 69,920 " | |
| | Ventilation........ ...... | 57,600 " | |
| | | | 223,520 |
| On second floor.............. | 1,200 sq. ft. glass × 80 = | 96,000 B.T.U. | |
| | 3,800 " wall × 18.4 = | 69,920 " | |
| | Ventilation.............. | 57,600 " | |
| | | | 223,520 |
| On third floor.............. | 1,200 sq. ft. glass × 80 = | 96,000 B.T.U. | |
| | 3,800 " wall × 18.4 = | 69,920 " | |
| | 6,300 " ceiling × 8.2 = | 55,440 " | |
| | Ventilation.............. | 57,600 " | |
| | | | 278,960 |
| | Total B.T.U.................... | | 736,000 |

or about 4,600 nominal square feet.

As stated above, it was found necessary to add radiation in the third story, giving off 55,440 B. T. U. more, thus providing radiation in that story for giving off 278,960 + 45,440 = 334,400 B. T. U., or about 50 per cent. more than in the two lower stories with about the same wall and glass surfaces and the same cubical contents.

The hot water starts from the circulator with a temperature a little over boiling point. It goes first to the radiators on the third floor, then to the radiators on the second, and last to the radiators on the first floor (one pipe system). The temperature of each radiator depends of course on the manner the radiation carried by each riser is distributed on the different floors. These temperatures are calculated for each radiator, and the actual radiation installed was computed from Curve I on Plate 2 in the paper. I read about my system here in the Society in January, 1904.

DISCUSSION.

Mr. Chew: We haven't heard very much from Mr. Edgar and his system for some time. I do know he has had experience in heating buildings of different heights. Whether there is more trouble in proportioning radiators on the top floors than on the middle floors is the question. I feel Mr. Edgar can give us something on that that will be of interest.

Mr. Edgar: I think from the statement made the gentleman (Mr. Reck) has made a mistake in figuring the job in the first place. He confesses that here. I think that the correction he made afterward was necessary.

Secretary Mackay: As Mr. Edgar says, the trouble in this case has been the same as in lots of other cases where possibly estimators get the floor plan of a building from the architect. He admits he knew nothing about the ceiling. He supposed or assumed there were air spaces there, when in actual fact there were no air spaces but the exposed roof of the building. He made a mistake in not making proper allowance for his exposed ceiling or roof. He put it in at the ratio that he employed for unfinished attics above, and found he didn't have an unfinished attic above. That simply changes the ratio from an unfinished attic to an exposed wall ratio, and necessitated increasing it just as much as that excess of wall space or ceiling space called for. He

acknowledged his mistake, shows the correction, so it doesn't leave much room for argument on the subject. It is the leaving out of these necessary points and not getting sufficient information about them that help to make failures in heating apparatus that are carefully calculated to suit requirements that don't exist.

Mr. Quay: I do not know whether the subject I am going to speak of is in line with the paper or not, but it has something to do with the top story of a building—our experience in one large building in New York. We figured originally on an investment of probably five or six thousand dollars for heating the dome, and the amount prevented the owners from accepting the proposition. They thought they would let it go. They were not going to use the top story for some time. They would take chances on it without additional radiation for this dome. It has been found since then that the radiation was not necessary. We figured radiation enough for the other parts of the building, but not the dome. Due to the sunlight and the design of the dome, I presume, the room had been very comfortably heated in the coldest weather without any radiation in this dome.

The question is, what is the experience of some of the members of the Society relative to heating domes and skylights over buildings, providing they are designed in such a way as to give the best light at all times of the day? I think this should be brought up before the Society.

Mr. Barron: Captain Reck's paper is interesting, and would be more interesting if he were here to answer questions. My experience with domes or skylights on top stories is, that the heating engineer usually puts in a great deal of heating surface there that is generally not used afterward, usually shut off, never any use for it because of the tendency of the heat from the lower floors to reach the top floor. I think it is not due so much from the sunlight or the heat from the outside as to the fact of the warm air going up from below. That is often figured on, and I, in the past, have figured on heat coming from the lower floors. Radiators would have to be added on the top floor because the heating surface was not sufficient, due to the cold roof and exposed wall—sometimes excess height, as Mr. Mackay explained.

Secretary Mackay: There is a difference between an exposed wall which always exists and a skylight or glass exposure which is helped by the sun. Green-house men only fire their boilers at

night and bank them in the daytime, saying they have more heat than they require from the sun through the glass construction, while at night when they have no sun they require all the heat they can get, having the coldest imaginable constructed building. They reverse the general order of things and fire their boilers in the nighttime and close them down and bank them in the daytime. The condition Mr. Reck ran up against is a permanent condition, an exposed wall not helped by the sun.

Mr. Barron: That is an excellent point Mr. Mackay raises, and I think he is decidedly right, and yet it occurs to my mind the sun does affect the roof of a building, assuming it is a plain roof and without any air space. The sun beating on that certainly changes the temperature. It is really an interesting point Captain Reck has brought up.

Secretary Mackay: In ordinary building construction there is an air space, and air is the best non-conductor we can get. As a result, we don't get the advantage of the sun through that air space which we would get through glass exposure which really radiates it.

I was connected with the water supply of a railroad for a number of years, in a very cold section of the country where the temperature drops to 30 or 40 degrees below zero. We put a water pipe in a box and then encased it in three feet of sawdust on all sides, making the box under the tank about six feet square. That water pipe froze solid and they could not thaw it. They took it all down. They then put up a water pipe with a box around it, and another one a foot square and battened, no sawdust there, and run the lower end into the ground and the upper end into the bottom of the tank. With the temperature 40 degrees below zero the pipe never froze. I merely bring this up as an illustration of the non-conducting qualities of air as against wood.

I think this is applicable to the air space between the roof and the top floor of any building. You have that air there, or non-conductor.

Mr. Barron: Of course, roof cooling varies in different cases. You know that from experience. This point brought up by Mr. Quay is interesting, because in church heating you know we never have put coils or radiators up around the dome. High churches are always heated fairly satisfactorily, and always have

been so far as I know. The modern practice throughout this country is where there is a large skylight or dome, the heating engineer designing the plant in every case insists that a coil shall be put around the base of that dome.

Mr. Kent: In regard to what Mr. Barron says, we have an example of that in the room where we used to meet. Until they put a coil under the skylight or dome the members complained of a cool blast on the top of their heads. It was necessary to put the coil there.

Mr. Barron: I am glad Mr. Kent brought that illustration up, for it covers the ground from our own experience.

Secretary Mackay: I had some experience with a church building in Boston, I believe the second largest church in the State of Massachusetts. They had a steam-heating apparatus for a number of years which was not satisfactory, and in addition to the immense amount of coal they had to consume there was trouble from the dome, one hundred and eleven feet high and fifty feet in diameter, with windows and glass on top. There was an immense exposure in front of the altar of the church. They got a continuous downward current of cold air, more objectionable on the altar than at any other point in the church because they had less opportunity for placing radiation there.

I was called in to design a heating apparatus to overcome the defects of the former apparatus, to reduce the consumption of fuel, etc. While working at it, one of our members, who is present, said to me: "Mackay, you will never heat that church in the world unless you put in electric fans to draw the air down." Another member of our Society said: "You will never heat the church unless you put a coil around the dome." I thought the electric fan proposition was a good one, because we had a ceiling there of 70 feet with a dome 50 feet in diameter and 111 feet from the floor of the church, and we had that large space to fill before we could heat the church. In arranging the radiation, I took into consideration the troubles they had experienced. I put what I call a solid apron of heat between the altar and this dome, 70 feet from the under side of the dome and 111 feet from the top of the dome. They have never experienced any trouble from the draft which they had formerly experienced in this church, which had been used for eighteen years previously.

I think, while it was a necessity in our 12 West Thirty-first

Street rooms to place radiation there to overcome the defect that existed in the heating apparatus, that a different arrangement of the original radiation, if it were possible, would have overcome that defect, which was remedied as Mr. Kent says. It, perhaps, was the fault of the original design which made this a necessity, and does not prove, in all cases, that it is an actual necessity to place a coil around the skylight.

One of the principal reasons why I did not put a coil around this dome was that I would have been carrying a water pressure on my boilers of 150 feet in height, or something over 60 pounds steady pressure on the boilers. As it is, I am carrying about 30 feet head of water instead of 150 feet. That was one of my objections to putting it up there. I did not want to have a steady pressure on the apparatus to accomplish the result of heating that glass space and preventing or turning away of that draft that formerly existed. That was not only in ordinary weather, but it was in weather the coldest I understand they have had—the first winter after the apparatus was in—the temperature being 13 degrees below zero.

I will mention that Mr. Kenrick, who resides in close proximity to the building and knows something of the conditions that formerly existed, the remedy applied and the after-results, is here.

Mr. Kent: Were the radiators on the floor?

Secretary Mackay: Direct radiators on the floor, in front of the book boards—lower than the book boards. A peculiar thing about the building is, while we look on radiators as unsightly construction, you can stand at the altar and with 8,000 feet of radiation in the church you cannot see a single radiator. They stand below this book board and behind columns, etc., finished in the same color and you cannot see them.

Mr. Quay: This is very interesting. It seems to follow that the necessity for radiation around the skylight depends almost entirely on the design of the skylight. I have heard from a man who works in a lithographic establishment on the top floor, where the skylights were designed, as he says, to get the very best light at all times of the day, and he says without any radiation in the room whatsoever, and with the outside temperature at zero, the men work in there in their shirt sleeves, and on very important work that requires very good condition of the hands, warm condition, without the least trouble whatsoever. He says at one

time he noticed the temperature was 85 in the room while it was zero outside. This is only hearsay. It is a question in what cases it is necessary and in what cases it is not necessary.

Mr. Barron: This is really an interesting discussion to me. The point Mr. Quay brought up is important. The lithographic establishment I imagine he refers to employed a great many hands, and, being Germans, they are pretty stout men and give out a good many heat units. That possibly helped the sun from the outside. All these things have to be considered. It depends on the individuals in the room and the conditions of each particular case. I have found, as Mr. Quay did, where coils had been provided for the top story, but it was not necessary to use them even in the coldest weather. You see there are really two sides. It depends on each particular case.

Mr. Brennan: I think it depends a good deal on the condition of the walls. Mr. Kent said they had to put coils in the room where we formerly met. I think there possibly might not have been radiation enough in the room in the first place. If the radiation had been distributed—for instance, we will take this room, and say there is a large skylight here (indicating) and radiators placed at that end and this end, and you would feel a cold draft coming down from this skylight, if you would put coils or radiators near the skylight that would counteract the draft. If they put radiators at the other end they would do the same thing, because the heat would have a tendency to rise to the ceiling and passing over the dome would come down and strike the centre of the room, being heated, whereas, before it was not heated.

I put in a heating apparatus in the central part of Wisconsin, designed by a Chicago architect, a shoe factory, fourth floor, and, according to the plans, we were to leave openings along where the skylights were, possibly fifteen or twenty skylights in the room and the room possibly four hundred feet long. The outside was surrounded by coils going around the outside walls. Those openings were left in case there was a downward draft from the skylights when we were to put in the coils. The temperature went twenty-eight degrees below zero, and we had about a pound of steam pressure on the coils. The windows had about twice as much glass surface as in this room in proportion to the wall, and we had possibly 80 degrees of heat in

that room—one large room. I think the circulation of the air was up to these skylights and then down to the centre. If we had not had sufficient radiation there, there would have been a cold draft from these skylights down on our heads.

Mr. Barron: Mr. Brennan's illustration is, I think, a very good one. Saying this is a closed room, with a glass dome in the centre, the air would immediately ascend to that dome instead of falling to the centre. As Mr. Brennan states, I think you will find it falling along the outside walls to the existing registers provided at the bottom of the walls. I think that is the course of warm air. The air ascending, would naturally go to the top.

Mr. Brennan: What I meant was that the warm air would counteract that cold draft. As Mr. Kent said, the cold draft came down and struck their heads. If there had been sufficient radiation, I hardly think it would have been necessary to put radiation in the dome. If there had been sufficient radiation in the room to heat it to 70 degrees, he would not have had that cold air striking him on the head.

Mr. Kent: The conditions are different there. They used to have it very hot in most places in the room, but those in the middle were complaining of cold air coming down on their heads. It seemed to come down as chilled air. I would like the Secretary to prepare a question on this subject and ask how would you heat an audience chamber, 50 x 30, with a high ceiling, say 20 feet, lighted by a glass dome overhead, the system being direct or indirect; that is, explain what rules you would lay down for heating rooms lighted by overhead domes.

Secretary Mackay: To get the matter straight on the records, I want to explain to Mr. Brennan that the place in question had no radiation in the room at all. It is heated by the hot-blast system in the basement. I am speaking of the necessity for an after-application of coil around the dome. That was placed after this heating system was put in. The hot-blast system is used in churches, halls, theatres, etc., and it was simply a question of a peculiar condition existing there. The original construction did not seem to accomplish the purpose desired, and, as a result, there were complaints. To overcome them, they made an application of direct radiation. The present system, as it exists, has all the radiating surface for that particular room in the basement or

sub-cellar. They afterwards made an additional application of direct radiation at the skylights to overcome the draft that existed. Whether it was due to faulty construction of the hot-blast system is a question.

Mr. Brennan: I think my contention remains the same. I think it was faulty construction of the hot-blast system and it was not necessary to place coils in the skylight. Now then, if this were the room, and they brought in hot air from this end and that end, and didn't bring any from this end, I think all that would have been necessary, instead of putting coils in the dome, would have been to put them in some places other than the dome and get the same results.

Mr. Monroe: Possibly in a room of this character, heated by the hot-blast system, the trouble could be overcome by ventilating through an opening placed in the skylight. You would not force out the hot air but the cold air, that is air that had become cool by coming in contact with the glass surface in the skylight. I think that always one must study the heating of rooms of that character, the proper placing of the radiators, the air inlets, and, also, the ventilating outlets, so that you will remove the cool air sometimes as well as vitiated air. It is, of course, necessary to remove the vitiated air.

But to return to the subject of the paper. I have been waiting to hear some one refer to the first three lines of the last paragraph: "In the building referred to the radiators in many rooms on the top floor have now 66 per cent. more heating capacity than the radiators in rooms on the second floor with equal window and wall areas, without being larger than necessary." That seems abnormal. I have been in a good many top stories of houses, but never have seen any such proportion as that used. I think, possibly, there must have been some defect in circulation—the radiators possibly not being filled with steam were not doing proper work. Of course we have to make sufficient allowance for the top floors of buildings over that of the floor immediately below it, to overcome exposures if there are any. Outside of that, as a rule, the top floor of a building can be taken care of, in my experience, with the same radiation that is on the floor immediately below it. As a rule, the top floor is one or two feet lower in height of ceiling than the lower floor, but that doesn't always follow.

I would like to hear some expression of opinion as to the proportion set forth here—66 per cent. I think, as I have said, if the circulation had been all right through the radiators placed in these rooms that the percentage could be very much reduced.

I want to suggest while on the floor that at our next meeting a question something on this line be propounded and ventilated among us: The height of a building that can be successfully heated with hot-water heating apparatus, owing to the water pressure accumulated by excessive height, where you use a cast-iron boiler—there is a limit, of course, to the height of the building—but what is that limit? I would like to be certain in my own mind. I have in mind now a building to be erected in Baltimore, for the *Baltimore News,* a seven-story office building, to be heated by a hot-water plant, basement circulation, the building being 135 feet high. Of course there will be an excessive pressure on the boilers. How high can we heat a building successfully with hot water?

Mr. Brennan: I think that the apparatus in Mr. Reck's building must have been faulty in construction. If he had about 66 per cent. more radiation on the upper floor than on the other floors there certainly must have been poor circulation of water. My experience has been with hot water that it goes up very easily, and with most of the apparatus I have constructed I found it hardest to circulate water on the first floor and not on the upper floors, and that the radiator would heat about 10 per cent. better on the upper floors than on the lower floor, and proportionately the second floor would heat better than the first, the third floor better than the second, and the fourth better than the third. So it is my opinion that the water was not as hot or there was not as good circulation on the upper floor as on the lower floors, and that the trouble was to a certain extent due to that cause and not so much to the cooling surface of the roof.

Secretary Mackay: I want to call attention to one point in Captain Reck's paper. It seems as though it would have been better had he been here to describe the construction of the building, the sizes of the radiators and things of that sort, because he tells us in his paper one square foot of radiating surface to nine square feet of ceiling area is his practice in his country to counteract the effect of these roofs with the air spaces between them, and that made 33 per cent. additional radiation in the

rooms. The rooms must have been small rooms. It seems to me that if one square foot of radiation to nine square feet of ceiling area makes 33 per cent. more radiation than the radiation in the rooms below, then one square foot to 4½, increasing it to 66 per cent., doesn't seem to increase the radiation very much, although it seems an enormous amount of additional radiation. It seems to be a peculiarly constructed building, and not the same as our average apartment houses, where we put thirty-six feet on the parlor and dining-room and on the floor below, and forty feet in the room above, of exactly the same size and area. I think there is something peculiar in the construction of the building. The radiators must be very small on the lower floors if the increase from 1 square foot to 9, to 1 to 4½, would give them 66 per cent. more radiation in the room. I think we are discussing the paper without a knowledge of the conditions, and it makes an unfair comparison.

Mr. Kent: I think the data are insufficient. It reads: "I had understood there was an attic (unheated) over the story, whereas in reality there was not, the protection against loss of heat being only a ceiling of lath and plastering, an air space and the ordinary sheathing, roofing-felt and gravel on the roof timbers." We don't know whether that air space was connected with out of doors or not. It is very common to find that an attic is actually open and the wind sweeps right through it. I know of a Sunday-school building adjoining a church where the air was found to be blowing through the attic. It may be these air spaces were not enclosed—dead air—but circulating air from the outside, which would make a very bad condition, and account, I think, for the 66 per cent. excess of radiator surface put in. It is necessary in attic construction to see that the air spaces are closed air spaces and not open air spaces.

Secretary Mackay: In discussing the paper, either Mr. Brennan or Mr. Monroe said there was faulty circulation, otherwise it would not have required this abnormal additional of radiation. He makes the statement that on the top floor of the building he didn't have sufficient radiation to accomplish results, although the same amount of radiation, less the amount computed for ceiling exposure, was sufficient, as I take it from the paper, to maintain the temperature on the lower floors. By the addition of radiation on the top floor from 33 per cent. to 66 per cent. he

was able, according to his paper, to accomplish the same results on the top floor as he did on the second floor. Consequently, the circulation must have been right, otherwise the addition of cold iron without circulation in it would not have helped to heat the top floor. I think, as he says, he merely made a miscalculation and did not understand the building he was heating, didn't understand that it had an outside wall exposure on the top as well as the sides, and he made no provision for it. He did not heat that. When he made provision, according to his methods of computing, for the wall exposure, he accomplished the desired results. His rule seems to have been right, but he did not apply the rule to that floor. He left out the ceiling because he imagined there was an attic there. He evidently did not have plans on which he made his figures.

The President: I want to call the attention of the gentlemen to one thing, and that is, if I remember aright, Mr. Reck had a scheme for re-heating the water up on the upper floor. Do you understand that that was applied in this case?

Secretary Mackay: As I understand it, it did not help the top floor of a building any more than any other portion; it did not increase the temperature or radiation on the top floor over that in the basement. He claimed one of the advantages of his system was with the superheating arrangement you could accomplish results where with the ordinary gravity apparatus you would have to follow nature's laws. I understand the top floor had no advantages over the first floor or any other floor.

The President: That was the point I wished to call attention to. If that arrangement had been as effective as was supposed, I do not think there could be any question about the water being heated to as high a temperature as it would be on the first or second floors.

Mr. Snow: In a number of successful installations, the amount of heating surface on the top floor has been increased by adding an amount based on the equivalent glass surface of the ceiling, which, with an unheated attic space, would amount to about $\frac{1}{20}$ of the ceiling area, and with a bare roof about $\frac{1}{10}$ the area. With the usual allowance for radiation of heat from direct steam radiators, these figures would correspond to about one square foot of direct radiating surface to sixty square feet of ceiling in the case of rooms with attic space overhead, and one square

foot of direct radiating surface to thirty square feet of roof, where there is no unheated attic. Since hot water radiation gives out about three-fifths as much heat per square foot as steam radiation, one square foot of hot water radiation would compensate for the loss of heat through eighteen square feet of ceiling with no attic space above as against an allowance of one square foot to every nine square feet of exposed ceiling recommended by Mr. Reck.

Take the case of rooms about 50 x 100 x 12, and compute the probable loss of heat from a room on one of the lower floors, then add to same the loss of heat through the roof. This gives an amount of surface on the top floor about one-third greater than that on each of the lower floors. That is, this would be the case under average conditions.

The 66 per cent. additional surface as stated in Mr. Reck's paper appears excessive. In the case of factories heated by the overhead feed system, if the mains and branches are left bare on the top floor the heat radiating from them will just about offset the loss of heat through the roof without any special allowance being made. Otherwise the radiation on the top floor must be increased to allow for the great loss of heat through the ceiling or roof as the case may be.

Mr. Barron: I would like Mr. Mackay to take up Mr. Monroe's question if he can remember the basis of it.

Secretary Mackay: Mr. Barron must be somewhat of a mind reader. I had intended to say something on the subject, and I suggest and make this motion, if in order, that a topic as to the height of a building which can be successfully heated by hot-water circulation be added and discussed with Mr. Brennan's paper on the circulation of hot water.

The President: It will be so arranged if there are no objections. (There appeared to be none.)

Mr. Vrooman: Professor Kent offered a suggestion a few moments ago that we have a discussion on what relation skylights have to radiation, the paper to come up at the next meeting, but I propose, in addition to that, that we add the word "ceilings," because in almost every rule you give in books you will find that they consider area or exposed glass surface, or exposed wall surface, and the word "ceiling" is almost invariably left out.

Mr. Monroe: As a rule, you don't always take the ceiling on the top story of a building as exposed surface. This is as much exposed surface as the wall is.

Mr. Vrooman: That is the point I want to bring out. I think the prevalent idea is to use a matter of judgment. I presume to-day among the trade—I do not speak of engineers—but among the trade perhaps more estimates are made and radiation laid out on the thumb rule than by any calculation of wall surface, or exposure, or anything an engineer would go by. The rule of one foot of surface to so many feet of space or air, perhaps, has more use than any other rule laid down. I do not say it is right, but it is practical. That, perhaps, is the cause of a great deal of trouble with badly heated buildings.

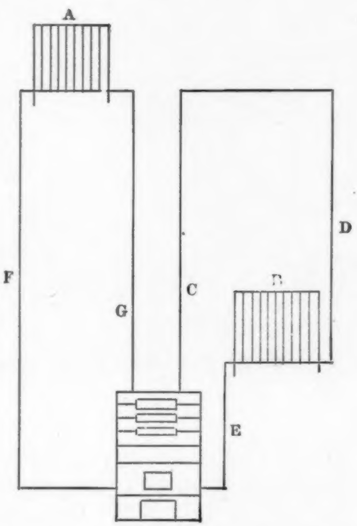
Secretary Mackay: Mr. Vrooman makes the statement that the short rule for figuring buildings is more often employed than the long rule, which gives the figures of heat losses. I think he is wrong there. I think that the short rule in the hands of inexperienced people is dangerous. The experienced engineer has his short cut to results, his actual experience in heating buildings, which includes his proportion for walls, glass and ceiling exposure, and in the hands of an intelligent person and a person of experience it is all right, while the inexperienced person would not place it properly, and as a result—failure. You would say it required a certain amount to heat this room while an inexperienced person might arrive at a wrong conclusion. While he has not actually measured up the square feet of glass with a lead pencil and paper, he has figured it in his head. These rules, sometimes called short rules, are rules employed by the engineer, but the inexperienced person attempting to apply them don't arrive at the same result.

## CXXXIX.

# THE CIRCULATION OF HOT WATER

BY JOHN S. BRENNAN.

The first cause of the circulation of water in a hot-water heating system, by the force of gravity, is that the water becomes denser as it cools off, and it therefore outweighs the warmer and lighter water and pushes it to the top of the apparatus. Hot water will move when there is a heavier and cooler body of water to displace it and force it upwards by means of its superior weight.




The force which propels the water in the risers and radiators is proportional to the difference in the mean temperature of the ascending and descending parts of the apparatus, and is also proportional to the vertical height of the circuit. For example—in a circuit or riser 50 feet high the motive force would be twice as large as one only 25 feet high.

The force of the circulation through radiators with a given fall of temperature depends mostly upon the height of the return pipe and is independent of the height of that portion of the riser pipe which is above the radiator. Take, for example, a radiator on the fourth floor, A, or 50 feet high, another radiator on the first floor, B, or 10 feet high, with both feed or riser pipes the same height. The circulation through the radiator on the fourth floor will be about three times as great as through the radiator on the first floor. Notwithstanding the fact that the supply column of both radia-

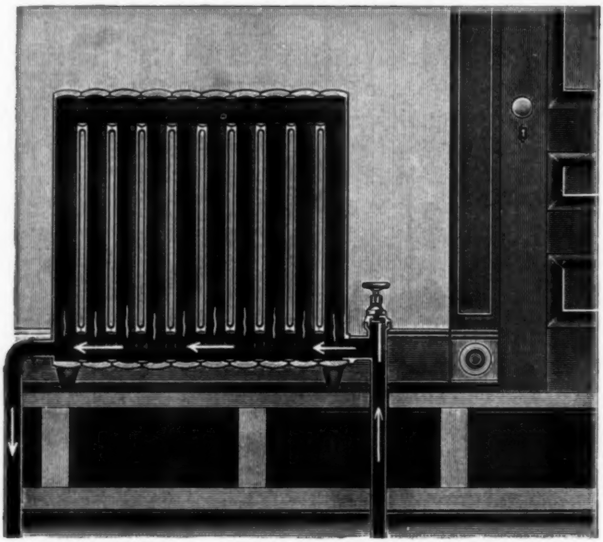


FIG. 1

tors are of equal height because the return, F, is about three times as high as the return, E, of the radiators on the first floor. The temperature of the pipes C and D are nearly the same, consequently the water in D simply balances an equal height of pipe C, and fails to supply any force for circulation. The force for circulation in this circuit therefore depends upon the preponderance of the weight of water in the return pipe, E, over the weight of that in the pipe C below the level of the radiator B.

Figure 1 is a fair illustration of a radiator with the usual

style connections. The force of the circulation through the radiator depends upon the height of the return column. The return pipe having a strong pull on the radiator the most direct path for the current is along the lines indicated by the arrows, and the water up in the radiator has a circulation which depends not on the force of the main current but on the tendency of the water cooled in the radiator to fall to the bottom and to be replaced by water flowing upward in the coils nearest the entering feed.

Figure 2 shows an improved connection to increase and

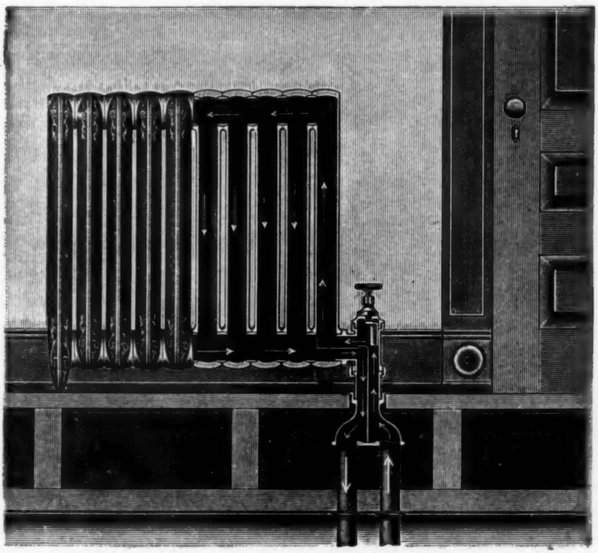


FIG. 2

improve the circulation in a hot-water heating system, which has been successfully used by the writer on a great many hot-water heating systems. The direction in which the arrows point show the actual current within the radiator. The hot water must pass directly to the top, dropping to the bottom, as it cools off returning to the return pipe. The circulation is positive and by actual tests the entering water is 6 degrees hotter than the circulation the old way, and, furthermore, the entire surface of the radiator is heated. I have compiled figures of tests of these two styles of connections for radia-

tors. A thermometer was placed on the feed and return section of each radiator, the connections on the usual style of radiator, columns 4 and 5, were 1½ inch inside diameter on the feed pipe, and 1½ inch diameter on the return pipe, the connections on the improved connection, columns 2 and 3, were 1½ inch connection with a partition in it with 1½ inch feed and return pipe.

| 1<br>Time. | 2<br>Return Therm. | 3<br>Feed Therm. | 4<br>Return Therm. | 5<br>Feed Therm. |
|---|---|---|---|---|
| 2:05 | 88 | 98 | 88 | 92 |
| 2:10 | 98 | 108 | 97 | 102 |
| 2:15 | 108 | 116 | 106 | 110 |
| 2:20 | 122 | 128 | 120 | 122 |
| 2:25 | 126 | 132 | 124 | 128 |
| 2:30 | 132 | 140 | 132 | 135 |
| 2:35 | 140 | 146 | 140 | 142 |
| 2:40 | 144 | 152 | 144 | 146 |
| 2:45 | 150 | 158 | 151 | 152 |
| 2:50 | 156 | 161 | 156 | 158 |
| 2:55 | 158 | 166 | 160 | 163 |
| 3:00 | 160 | 172 | 163 | 170 |
| 3:05 | 166 | 178 | 173 | 165 |
| 3:10 | 172 | 182 | 177 | 180 |
| 3:15 | 176 | 186 | 182 | 184 |
| 3:20 | 180 | 190 | 186 | 188 |
| 3:25 | 184 | 194 | 190 | 192 |
| 3:30 | 189 | 199 | 196 | 198 |
| 3:35 | 192 | 202 | 198 | 202 |
| 3:40 | 196 | 206 | 202 | 206 |
| 3:45 | 200 | 210 | 206 | 209 |
| 3:50 | 206 | 212 | 208 | 212 |
| 3:55 | 208 | 213 | 210 | 213 |

Column 1 is the time in which the test was made. Column 2 is the top return section of the radiator with the improved connection, and column 3 is the thermometer on the feed section of the radiator with the improved connection. Column 4 is the thermometer on the return section of the radiator with the old style connection. Column 5 is the thermometer on the feed section of the old style radiator connection. The radiator with the old style connection, columns 4 and 5, is a 13 loop 38 inch high Corinth radiator, containing 71½ sq. ft. radiating surface. The radiator with the new style connection, columns 2 and 3, is a 24 loop 14 inch high Unique radiator containing 96 sq. ft. of radiating surface. It will be noticed that the thermometer on column 3 or feed pipe of improved connection is higher than the one on column 5 or feed pipe of old style connection, it being six degrees higher and remaining somewhat higher until the thermometer registers 212 degrees.

The principal object to be sought in designing a system of hot-water piping is to adjust and equalize the resistance in each circuit and branch so that the hot water will flow with equal readiness to each radiator. This is accomplished by making the diameter of each pipe just sufficient to pass the desired amount of water under the head or drawing force which is available in that particular part of the system.

Heretofore a great many people objected to hot water as a means of heating on account of the radiators having a connection at each end, and when any cleaning or painting was done behind the radiator it was necessary to drain the water from the radiator and disconnect it from the flow and return pipes. This necessitated shutting down the apparatus until the radiators were connected again.

The trouble and annoyance incident to setting and connecting a radiator with two pipes in or above the floor in the usual way are avoided by this improved connection which requires but a single opening to be cut in the floor and a single coupling to be made above the floor. This improved connection by its peculiar construction allows a radiator to be swung away from the wall without interrupting the circulation of the water. This is very useful when using the apparatus when the building is being erected. The heating apparatus can be installed complete and the radiators swung out, and when the building is completed they can easily be swung back in place again.

DISCUSSION.

Mr. Cary: The method employed by Mr. Brennan to show the efficiency of his radiator may be a correct one or it may be totally wrong.

For this purpose, I see that he takes the temperature of the steam entering the radiator, and at the same time he notes the temperature of the steam and water leaving the radiator. The difference is very small according to his statements, one or two degrees in some cases.

The average difference in the reading of most thermometers commonly used in such work is over two degrees, so I would like to ask Mr. Brennan whether he carefully compared his thermometers one with the other, and noted whether both read alike.

Mr. Brennan: I did.

Mr. Cary: That is a most important matter for such observations. A statement showing the mere difference in temperature between the inlet and outlet of a radiator gives us very little information concerning its performances unless we know the quantity of steam passing through it during such a test. What we wish to know is the quantity of heat (expressed in British thermal units) which is radiated in a given time, which requires a knowledge of the number of pounds of steam used as well as the temperature determinations.

A small quantity of steam supplied in a given time may have a very large temperature drop, while a large quantity of steam used during the same time may have a very small drop in temperature.

I do not find, in Mr. Brennan's paper, a statement which would give us this most necessary information.

Secretary Mackay: I read Mr. Brennan's paper with a good deal of interest, being more or less connected with the application of hot-water circulation. He makes a statement in the first of his paper, on the second line, and says: "The water becomes denser as it cools off, and it therefore outweighs the warmer and lighter water and pushes it to the top of the apparatus." Now, in looking at these two cuts, and in considering the general application of the apparatus, I cannot understand why this first clause of his paper would not apply to Fig. 1 as well as Fig. 2.

Then he makes reference to the old style of radiator and the new style of connection which he speaks of here. I want to correct him in that. In the former construction of radiators for hot water—I might say the first construction for hot water—we considered that it was necessary to block off the first loop of the radiator at the bottom so the water would take its course into the radiator, up the first loop to the top, as Mr. Brennan has shown here in Fig. 2, then along the top and down the other loops to the return. That gave what we considered was positive circulation, and would do away with the possibility of short circuits and all those enemies we had to contend with and which we had to overcome before we could successfully apply a hot-water heating apparatus.

I conducted some tests at the Griffing Iron Works, some eighteen years ago, where that question was under discussion in the

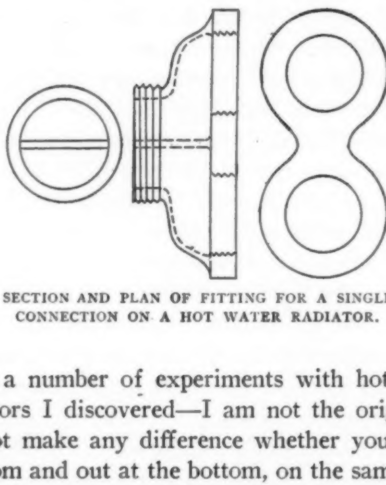
old Bundy radiator. We put these up in a shed and connected them with a hot-water heating apparatus. The radiators were the only construction we had known up to that time—this improved construction. We found we got equally good results, or if anything better results, by allowing the water to ascend in as many loops as it would and descend in all the others. The radiator we found was merely a tank that held the water, that if you introduced heat at any point it rose to the highest point and went down without the necessity of any special device or anything of that sort. We had a peculiar experience there which I think worth while mentioning here. In cold weather when we would start up the apparatus, when the temperature out of doors was perhaps down to around zero, it was impossible to get any circulation in these radiators until you had completely filled them with water, and before they were completely filled they were frozen solid. We had to go around with torches over the return pipes and radiators before we could get circulation

In the newer construction, where you enter the water at the bottom and take it out at the bottom, regardless of whether you take it out at the same end or the opposite end, so long as there is one-eighth of an inch of water in the base or sufficient to connect the flow and return pipes you have circulation, and the bottom of the radiator was as hot as the water in the boiler less the loss of heat from the boiler to the radiator. We had no trouble from freezing. We had no trouble from the circulation, and we positively got better results. I attributed it to absence of the friction caused by putting in a device to compel the water to take a sharp turn.

Now, there are two different ways of describing circulation. One says heated water, being lighter, will flow to the top and compel the heavier water to go down. The other is that the cold water being heavier, dropping will compel the lighter water to ascend. It is something that is in common practice in every house in the United States that has plumbing in it with hot-water circulation. Without the need of any special device the water heated in the water-back will go to the boiler. This is going on every day with success. Devices for accomplishing it have not in my judgment done as well as the old method.

Another point. We originally thought it was positively necessary to enter the water at the top of a coil and take it out at the

bottom, and in a radiator to bring the water in at the top and take it out at the bottom, at the opposite end, a positive necessity in applying hot-water circulation. Some trouble from freezing took place there. I have since discovered that it is not any further from the top of a radiator to the bottom of it, inside of it than it is outside of it; that if a radiator is three feet high on the outside, it is three feet high, less the thickness of the metal top and bottom, on the inside, and if you bring the water in hot it has got to go to the top and go across and down, and it doesn't make any difference whether you put your connection outside, on top or at the bottom. The only point of advantage it had was that you didn't have to stoop to open the valve. They got over that by giving you a valve you can kick with your foot.



SECTION AND PLAN OF FITTING FOR A SINGLE CONNECTION ON A HOT WATER RADIATOR.

In making a number of experiments with hot-water circulation in radiators I discovered—I am not the originator of it—that it did not make any difference whether you took the flow in at the bottom and out at the bottom, on the same end or opposite ends. I also discovered if conditions were such that you could not get across to the opposite end you could take the ordinary radiator and put two connections on one end.

I have shown a special fitting made up some years ago. I would take a radiator and put an ornamental plug in the opposite end, screw this fitting in, which would make the connection slightly longer still; that enabled me to take the ordinary hot-water radiator, constructed in the ordinary way, plug up one end and screw it in, making the connections as large as one and a half inch at times. Naturally I didn't get as much

area, but I found I got equal results as with opposite end connections and it didn't short circuit. It lay flat, so the flow of hot water and the return water went in and came out on the same level. I found there was not any difference with the same radiator whether connected at the top or at the bottom.

Mr. Brennan makes another statement here, that in this figure, which is lettered and not numbered, that a better circulation is obtained in "A" through "G" and "F" than would in "B" through "C" and "D." I do not know what provision he made for the exhaust of his air along the top line there, but his results are exactly opposite to what has been done in the average hot-water plant. I have found it in practice of a good many years, that I can by an overhead supply reduce the area of my mains from 20 to 25 per cent. in hot-water circulation, and I think that is the average experience of the men doing hot-water heating. I can do that with any overhead supply system over what I can with the under supply, all the radiators being of the same size.

It seems to me there must have been some peculiar conditions in connection with his tests; he did not extract his air properly, or something of that sort. Air, of course, is the worst enemy we have to contend with in hot-water circulation, and the presence of it will as effectively stop circulation as if you had an expensive gate valve. That statement would seem to upset all the theory and actual practice in applying overhead hot-water system as against an under supply.

A Member: I was under the impression something you said at a previous meeting showed you believed that we often made a mistake in getting too large a flow.

Secretary Mackay: I think we can go as far in that direction as the other. We can make the pipes too small and interfere by friction or too large and interfere with controlling the apparatus by raising or lowering the temperature and by short circuiting. (Addressing the President.) I understood, although you did not announce it, we are to couple with this discussion the topic proposed by Mr. Monroe: "What is the greatest height of a building which can be successfully heated by a gravity system of hot water, taking into consideration the pressure on the apparatus due to height?"

The President: That was understood.

Secretary Mackay: While I have not any positive informa-

tion as to actual measurements in feet, I would mention that Baker, Smith & Company, some four or five years ago, installed a hot-water heating apparatus in New York, where it was ten stories above the street—the boiler being in the sub-cellar. The first floor was about five feet above the sidewalk. The basement would make it eleven stories, and they would average, considering the thickness of the floors, etc., about fifteen feet, so that there would not be any less than one hundred and thirty-five feet.

In the Polytechnic Institute they have had an apparatus in use for twelve or fifteen years where the height to the top of the water is 120 feet.

In the Odd Fellows' business block, in New Bedford, Mass., they have had a heating apparatus in use for fifteen years where the building is a six-story building and the tank is up in a tower one or two stories above, and from the tank to the boilers is something like 110 or 115 feet.

These are three cases that I know of. Take fairly high buildings, there are lots of them five, six or seven stories, being heated from year to year without any trouble.

In this particular apartment building in New York, ten stories, it was a question with them about the construction of the valve that would stand the pressure, leaking, etc., under that excessive head. While they felt the boilers, mains, etc., would stand it, they were in doubt as to the movable parts. They expected leakage there. I was called in in connection with that, and as far as I know they had no trouble from the valve suggested. Had there been trouble I think I would have heard from them. A leak there would have been a bad thing. That building is the tallest building I know of heated by hot water, except, I understand, the Mormon Temple, in Salt Lake City, is a very high building and heated by hot water. I understood at the time I was connected with it that the boiler manufacturers had to give a guarantee that their boilers would stand 200 pounds steady pressure.

Professor Kent: Is there any automatic fitting that could be used to draw off the accumulation of air in the top of the radiators?

Secretary Mackay: There have been, but that is one point where the overhead system gets rid of it. We come down with one pipe instead of two, connecting into the radiator top and

bottom at the same end, and frequently back to the same main, and then you relieve the system of air at the highest point. You get rid of the air. Whereas, in the ordinary apparatus you have to have an automatic air valve which has not, in my experience, been found to be successful. With an ordinary air valve it is not a matter of much manipulation except on the top floor of the building. The air valves don't have to be operated the entire winter.

There are different ways of doing it. Some pipe the apparatus in the ordinary way and then take an air pipe from the top of each top floor radiator, which is not as objectionable as taking from all radiators. Some pipes are run at a point where they freeze, and might also be broken by expansion. The ordinary key air valve is used where they put a top feed and bottom return. They put the air valve at the opposite end more as a guide in filling up the apparatus, to let you know where the water is.

I find no automatic devices that would remove the air from the hot-water heating system as well as the overhead system with a single connection. I use exactly the same thing in indirect hot-water radiation. I have seen indirect hot-water apparatus where they made the radiators the same as shown in these figures. I think the simplest and best way to pipe for indirect radiation is to pipe it similar to what you would low pressure steam. That way, to my mind, is simpler, better and surer, and always insures the radiator being in operation as long as there is fire in the heater and water in the apparatus, with the exception of rooms on perhaps the third or fourth story, which are not so important. I have frequently used the same main for indirects as for the directs, but the objection to that plan is that the upper radiators will draw water from the lower ones. The customary practice has been to run separate mains for the direct radiators from the boilers and separate mains for the indirect, so that they can be valved off separately and so that the upper radiators could not get water intended for the indirects—consequently insuring more uniform distribution of the heated water—the entire first and second floors heated by indirect radiation and the third floor by direct radiation.

Mr. Monroe: Isn't it as practical in a system where the main flow and return is in the basement to make the connection to the

radiators at the top and let the water pass on out through the riser, venting the top-floor radiators with air valves?

Secretary Mackay: That could be done, but there is a possibility of breakage by expansion and contraction, and there is a possibility of robbing your first floor radiators. You are taking out the hottest water from the radiator where it accomplishes nothing except to draw the water away from that radiator. The trouble from air has been on the upper floors of the buildings, and while there is a certain amount of air in the water all of that goes to the top. It is there where your trouble is from air, if it exists at all, and not on the first floor.

Mr. Monroe: I am taking the feed connections going to the top where the return connection goes under the bottom. The air will pass up through the feed connection until that radiator is filled with water.

Secretary Mackay: The condition Mr. Monroe mentions brings us right back to the trouble I have experienced in circulation and in the freezing of radiators in new buildings, possibly cutting off your circulation if you haven't got that air connection, and you have got to have that radiator full of water before you get circulation. The moment the water gets below the top pipe, which may be one and one-half inches from the top of the radiator, you have no circulation. Taking off an air pipe won't help the circulation in that particular radiator. Of course, you can fill it with water and it will insure circulation. The moment it gets below the top your radiator stands full of water. The principal objection I have to the air pipe is possibility of breakage and the unsightliness of it.

Mr. Brennan: In regard to the several objections Mr. Mackay has made to this style of connection, I might say that the connection that he has drawn on the blackboard, and where he claims the circulation is connected to both ends, I experimented with, and, if you will notice in Fig. 2, the partition is extended to the first push nipple. It is not so tight that it excludes water from passing through into the radiator, but this partition was arranged so that it was about midway or in the centre of the first section of the radiator. The test was then made and the circulation in this radiator was from 10 to 15 degrees cooler than with the old style of connection. If this radiator was air-bound at the top there was still circulation enough to keep the radiator

from freezing, providing it was not too cold in the room and the windows were not open.

There are objections—some objections can be found in the most kinds of heating apparatus. The overhead system will not circulate until all the radiators are completely filled with water. I had a case of a four-story building in the country, with the overhead system, where we had to pump water, and before I could get the water to the fourth story I had pretty nearly all the radiators frozen up. The freezing up of radiators in a new building this connection would obviate to a certain extent, because where you use radiators for temporary heating it is usually the practice to connect the radiator with pipes, extending the radiator out so that the workmen can get behind it to do the finishing.

The tests, or tables, which I give on page 2, show simply an idea of mine. I come across a heating man and he says he puts in the overhead system and gets best results, gets more hot water, better circulation, and with smaller mains, etc. Another man says he puts it down in the basement and wouldn't put in anything else. Another man says he connects at the top and goes out at the bottom, at the same end.

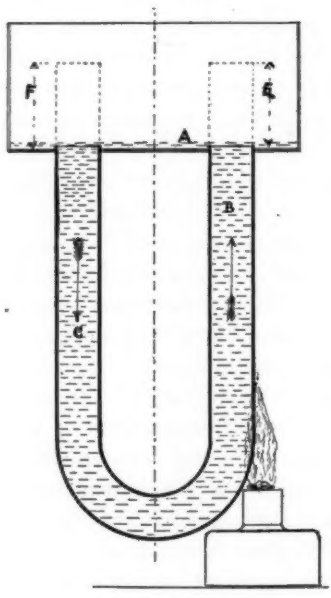
While I have put in a number of different apparatus, I have made no actual tests as to temperatures or as to what these different styles of radiators would do until the present test. I did not make tests enough to satisfy myself, and the reason for presenting this paper this morning is just to get this discussion as to the merits of hot-water heating. Whether the overhead system will heat or take more heat units from the fire than the system in the basement is what I want to get at, and get if possible an accurate test of the different systems of heating together with accurate reading of temperatures on the different floors. I do not say that this connection I have is the only connection, but it is just simply an experience of mine.

Mr. Cary: The principle governing the circulation of water in heating systems is comparatively simple from a hydraulic standpoint, and it can be easily illustrated by taking a simple U tube, such as I have shown in Fig. 1, having the top of the two legs opening into a common chamber or vessel.

When this simple apparatus is in use, leg B will contain the ascending current of hot water representing the supply pipe of

our system. As this water leaves the boiler, and after entering the expansion tank, which is represented by vessel A, it descends along the leg C (which represents the return piping) and passes to the boiler. When this circulating water is again heated in the boiler, the water will, of course, pass up along the line of the supply pipe represented by leg B, and so continue this cycle of circulation.

The reason for this action of the water in our circulating




CIRCULATION OF WATER.

system is very simply accounted for when we remember that the column of water found in leg C, and, therefore, the weight of the column of water in the leg B, is lighter than that contained in the leg C.

Let us now, for example's sake, extend the top of leg B so that it will rise to the height shown by the length E, while we make no change in the length of the leg C.

By again heating the water in the leg B, its weight per cubic inch is reduced, so that it may rise to the top of the extension E, and the heavy cold water contained in the leg C will just balance

the weight of the lighter water contained in the leg B to the top of its extension.

Under these circumstances no circulation whatever would take place in this system as the weight of the column of water in both legs, although extending to different heights, will just counterbalance one another.

In such a case the height 4 will represent the head or additional height of the column of water in leg B which causes the water to circulate.

This is merely a case of water flowing from a higher to a lower level, an example with which we are all familiar, and the velocity of flow in feet per second while h represents the height from the formula $V = \sqrt{2\ g\ h}$. V in this formula represents the velocity of flow in feet per second while h represents the height shown by the distance E, illustrated in our drawing, and g is the acceleration due to gravity or 32.2.

Unfortunately, it is impossible for water to circulate in a heating system at this velocity, owing to the friction it meets with in passing through supply and return piping as well as when passing through the boiler, and also on account of minor obstructions.

In hydraulics, the height E is termed the "flow head" or the "velocity head," and in order to obtain a corresponding value which will represent the friction in the pipe, it is customary to consider this friction as equivalent to what is called a "friction head," which latter value is obtainable by calculation.

The friction in the pipe would produce identically the same effect as though we extended the height of the leg C above the line A, as is shown by the dotted line F in the drawing.

It is sometimes found in improperly installed heating systems that the friction is so great there is no circulation whatsoever through the heating system, in which case we would show the friction head at least equal to the height E, as is shown on top of the leg C and indicated by the distance F.

Under such conditions it is easily seen that with the flow head E and friction head F extended to the same height no circulation whatsoever will occur in our heating system, and, therefore, it is very important to see that we have an ample area in our pipes and through our valves and other fittings, as well as through

the boiler, in order to insure a perfect circulation in a heating system, and the height F should be kept as much below the height E as is practically possible to insure a perfect circulation in our hot-water heating system.

Professor Kent: I wish to ask Mr. Brennan about this table on page 4. What are the conclusions to be drawn from that table? He has not summed them up nor made averages and not put them in shape to convey what they do mean.

A statement on page 5 seems a misprint. It says columns 4 and 5 and the figures don't correspond with the figures in the table. I cannot get anything out of the table except that there is a smaller difference of temperature between the feed and the return with the improved system than with the old system. In order to make this test complete we would have to have meters on the pipes to show the amount of water going through the radiators, as well as the temperatures. Temperatures are not the whole thing.

Mr. Brennan: These tests I have made were simply to bring out discussion. Column 5, on page 4, is the feed temperature of the radiator, with the old style connection, and column 4 the return. These were changed in printing. It is a little different from what I had it in the rough, but the printer and Mr. Mackay thought it better to change these different columns, which is why it is a little confusing. The idea I wished to bring out here and impress upon you was that in constructing and designing hot-water apparatus a good deal depends on the manner in which you construct the pipes, and that the largest pipe doesn't always give the most hot water. I have noticed several times where you have a hot-water valve with a small opening in it to keep the water in the radiator from freezing when you shut the radiator off—it had an opening about as big as the point of a lead pencil—the radiator would sometimes stay warm until all the water was cool. It was almost impossible to shut off the circulation of water in the radiator, and oftentimes I have had to go and solder that opening up.

Now, as the gentleman has shown in the drawing on the blackboard, my idea is that the radiators on the first floor are much colder than on the second floor, and the radiators on the third floor much hotter than on the second floor. I have endeavored to get a discussion of this question as to the merits of the different

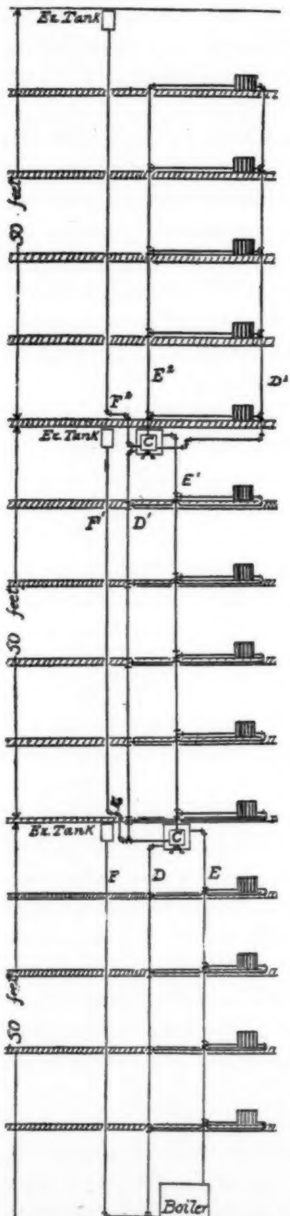
systems of heating. These tests I have made are not technical, but merely a practical illustration of what I have done in this particular case. As I said in the first place, there is not anything technical about it.

These tests were made with different kinds of connections, and as I explained in the start, the reading of the temperature in the different columns was to show that the object sought in designing a system of hot-water piping is to adjust and equalize the resistance in each circuit and branch so that the hot water will flow with equal readiness to each radiator. This is accomplished by making the diameter of each pipe just sufficient to pass the desired amount of water under the head or drawing force which is available in that particular part of the system.

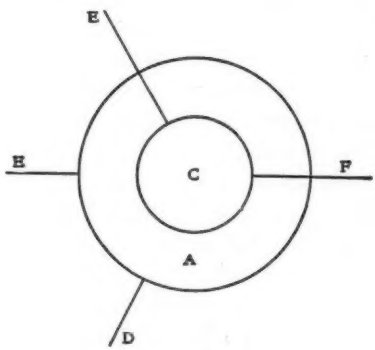
Secretary Mackay: Mr. Kendrick has asked a question. It was to arrive at some conclusion that these tests were made. We found it made a difference—while heating the radiator as uniformly as with the division in—a difference of from 10 per cent. to 15 per cent. in time. That is, the radiator without the division heated up to 10 per cent. to 15 per cent. quicker than with the division, and we attributed that to the trouble we all experience in hot-water heating, friction, when you attempt to turn a volume of water quick and short—long-turn elbows in hot-water heating are of advantage. We have a space of one inch on the inside of a radiator, and we turn the water abruptly in that space, whereas in the open-spaced radiator the water flows through with little friction.

There is one other point. Mr. Cary makes a drawing of hot-water circulation. Those who have had experience with placing hot-water heating—I think Mr. Brennan will agree with me—the statement is made that it is impossible to hold cold water above hot water in hot-water heating apparatus. It is done time and again. We find in our experience where water passing from a radiator will get into the return pipe at a higher temperature than the water further along the line in the same return pipe and will hold the other radiators in check and cold while there is a high temperature at the heater.

Mr. Vrooman: A gentleman proposed the idea of how to heat a high building with hot water without excessive pressure. It might be done by dividing the system into sections. The accompanying drawing is divided into three sections of 50 feet each.




METHOD OF HEATING A HIGH BUILDING WITH A HOT WATER SYSTEM, WITHOUT EXCESSIVE PRESSURE.




Section through Tanks

The boiler heats the tank A, which contains a separate tank C, inside as shown. The principle is the same as is used in plumbing where a double boiler is utilized, and one boiler is connected to the tank and the other to the water back.

A = Exterior tank.
C = Interior tank.
D = Return from tank A to C. Also from radiators.
E = Flow to tank A from C. Also to radiators.
F = Expansion pipe.

## CXL.

# THE ART OF HEATING AND VENTILATING AS PRACTISED FIFTY YEARS EARLIER.

BY R. C. CARPENTER.

It had been the intention of the writer to give an extended résumé of several early works on Heating and Ventilation in order that opportunity might be given to contrast our present practice with that common fifty years earlier. A press of other work has prevented me from giving the necessary time to this article to make it of much value historically, and I can only hope to suggest in the short time which I have had for the preparation some topics for discussion to those who are qualified to discuss the present methods as compared with those used much earlier.

I can at best hope to make only a few general observations.

One conclusion which I think can be stated in contrasting the work done in this art one-half century earlier with that to-day is this: the improvements which have been made are principally in the line of manufactures such as can be comprehended under the heads of materials, workmanship and art. There have not been any great or radical changes in methods and systems of heating and ventilating, so far at least as the descriptions in the various books at hand indicate. Fifty years ago there were few manufactured articles on the market in any country of the world for the erection of heating and ventilating systems, and it was necessary in a great measure to use articles of special design and manufacture.

Thus, for instance, if you refer to the work of Thomas Tredgold, published in London in 1836, you will find that at that time a steam-heating engineer would have been in possession of approximate methods of computing the loss of heat radiated from buildings and of corresponding methods for computing the necessary size of radiating surface to supply the required heat. You will find, however, no standard or manufactured forms of

heaters or radiating surfaces existed, and that consequently it was necessary for the heating engineer to also be his own manufacturer and designer and construct his own heaters, radiators, etc.

Tredgold's book referred to above states that steam pipes may be made of cast iron, lead, copper or wrought iron, but in practically all the examples cited cast-iron pipes are shown. Regarding the various joints for pipes, Tredgold gives preference to the flanged joints packed with a "flat plait of slightly twisted hemp yarn which has been previously saturated with stiff white lead paint." He also speaks of making joints by facing the flanges and using for packing a strip of tin. He had even found out at that time that lead was too compressible to be used instead of

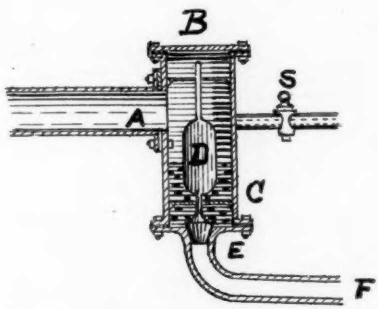


FIG. 1.—FLOAT TRAP SHOWN BY TREDGOLD.

tin for this purpose, as it contracts permanently. He also speaks of the use of iron cement for flanged joints. The use of spigot and faucet joints, which were then common for water pipes, he states are not well adapted for steam pipes because there is no provision for holding the parts together.

Tredgold states that wrought-iron pipes are joined "by making the lengths that are to be put together each to screw into a piece of pipe of larger diameter," which is practically our method at the present day. For the purpose of taking up expansion, Tredgold recommends that a drum of thin copper be employed which may be compressed or extended without injury, and states that such drums were used in steam pipes supplied to warm the lecture room at the Royal Institution. He states that the expansion may be taken up by connecting the pipes to a short length

of smaller pipe arranged to slide in a stuffing box, but the drum he considers preferable.

Tredgold's work shows that he was well acquainted with the design and construction and use of steam traps for removing the water of condensation, two kinds being illustrated, one a float trap which is perfect in every detail, and the other a siphon trap made by connecting the return pipe with a U-bend, of which the legs were long enough to overcome the pressure due to the steam.

The boilers shown in Tredgold's work are both cast iron and wrought iron. The cast-iron boiler is of spherical form without internal tubes, and it is set in brick casing so arranged as to cause the heated gases to encircle the sphere in a spiral path. The

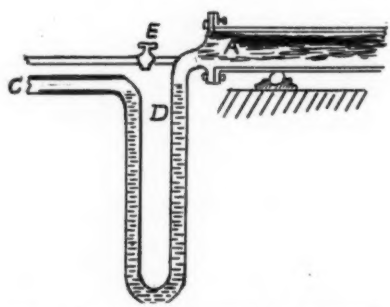



FIG. 2.—SIPHON TRAP SHOWN BY TREDGOLD.

wrought-iron boiler is of cylindrical form without any internal flues and is set in brick work so as to be encircled by the heated gases. The boiler is provided with a safety valve, opening inward to prevent the formation of vacuum, and a combined cover and safety valve, opening outward, the manhole cover being held on by a bar designed to give way should any excess of pressure come upon the boiler.

In the steam-heating system shown by Tredgold the condensed water is usually returned to the boiler by gravity, his direction for piping being as follows: "The steam pipes proceeding in the nearest course to the highest point where steam is required and then descending to the lowest, from which the small condensed water pipe returns the water to the boiler. Unless you want heat in the places through which this small pipe is to pass,

let it be surrounded with slow conductors of heat, so that as little as possible may escape."

He states that when the boiler is not sufficiently low to receive the return water, then it may be necessary to adopt other schemes, and he describes a very ingenious method of raising the water of condensation by means of the steam pressure acting on one leg of a U-shaped piece of piping, so connected as to raise the water in the other leg high enough to enter a tank, from which

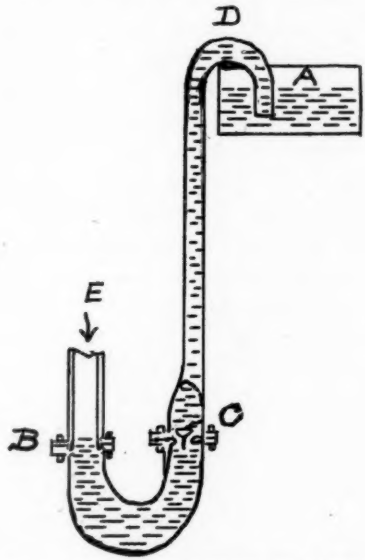



FIG. 3.—TREDGOLD'S METHOD OF LIFTING WATER OF CONDENSATION.

it will flow to the boiler, the water level in the boiler being regulated by a float valve.

Tredgold expressed an opinion very unfavorable regarding the use of heating with hot-water circulation, and it is quite possible that he did not appreciate the force which caused such circulation.

Tredgold's book is ample evidence that the art of heating with fireplaces was rather more advanced in his day and time than at the present, principally because they were more used. He gives detailed descriptions of fireplace constructions designed to utilize the heat to the best advantage, and discusses the

methods to be followed in securing perfect combustion and best results.

The treatise on Warming Buildings, by Charles Hood, written in 1844, is principally devoted to the method of heating with hot water. In general, the same observations regarding practice at his date could be made as in respect to the time of Tredgold. His work shows an excellent understanding of the principles of heating by hot-water circulation, his methods being limited by the materials and workmanship available at his time.

Both Tredgold and Hood consider methods of ventilation as well as heating and approximate rules are given for the motion of air in flues which is caused by a difference in temperature.

In 1844 Dr. D. B. Reid wrote a work on "The Theory and Practice of Ventilation," which is a classic in its line even to the present day. Dr. Reid's treatise shows that the science and art of moving air by difference in temperature was probably as well advanced as at the present time, and he gives detail drawings of the construction of the ventilating system in the House of Commons and full description of the results of the various experiments in that building. His description of the ventilation of the House of Commons is well worthy a place in our Proceedings.

Dr. Reid also describes a number of forms of fans or blowers which indicates that in many cases these were frequently used at that time for forcing in fresh air from the outside or exhausting it from the inside. The blowers, or, as Dr. Reid calls them, "fanners," while well known, were evidently not used to any great extent at his time, probably principally because of the difficulty of obtaining power.

The works of Peclet were printed in France about the same time as the books previously referred to, and these also illustrate the same propositions which I stated at the beginning of the article, and will not be further referred to in this particular time and place.

It will, I think, be generally admitted that all our processes of heating were known in a general way fifty or sixty years ago, that our improvements have been principally in the lines of details of manufacture, in adapting materials to a greater field of usefulness, and in working up standards for manufactured articles. The effect of the improvements has been, first, a great

reduction in the cost of the heating plant; second, greater economy in the use of fuel, and, third, a greatly extended application of the improved systems and methods of heating.

The American excels practically every other nation principally by his engineering ability, which is manifested by the production of simple and effective designs, by improved methods of manufacture by which the cost of construction is reduced and the quality improved. The ability of the American engineer along such lines is nowhere better illustrated than by the thousand and one, perhaps ten thousand and one, standard articles which have been constructed to meet every possible phase of demand for the heating and ventilating of buildings. As illustrations we have our standard pipes constructed of steel or wrought iron of any size desired; for these pipes we have an almost countless variety of standard valves and fittings. We have radiators in cast iron or steel of almost endless shape and variety and sufficient to meet almost any possible conception or demand of the user. We have standard heaters designed on scientific principles of so many varying proportions, sizes and shapes that no demand can arise which cannot be filled. This list could be almost indefinitely extended; it serves to show that the art of heating and ventilating has greatly improved in the last half century. My previous remarks show that its improvement has been more greatly in engineering and manufacturing lines than in scientific or philosophical lines, still I do not wish to convey the impression that we have made no progress in the use of new processes for heating or in the application of scientific principles to new purposes, for I think as an illustration it will be found to be true that vacuum systems of heating which are now common with us were not described fifty years ago, and doubtless many of the gentlemen here present will call attention to other recent improvements not referred to in the early publications.

I regret exceedingly that my time of preparation was not sufficient to cover the field in a more satisfactory manner, and I trust that the discussion which I hope will follow the paper will make amends for its deficiencies.

## DISCUSSION.

The President: You have heard the reading of Professor Carpenter's paper. Are there any questions any gentleman would

like to ask Professor Carpenter on these points? If so, I am sure he will be pleased to answer them.

Mr. Barron: That contribution opens up a field of thought which is very interesting I think to most of us—the looking back to what they were doing a half century ago and what facilities they had for doing it.

He refers to Tredgold's work being published in 1836. My recollection is Professor Carpenter has overlooked the fact that Tredgold's work was originally published in 1808—if I am not mistaken—and that 1836 edition was a re-issue by T. Bramah & Sons. Tredgold's books took a position as against hot water and Hood's work rectified that position and changed the attitude of the engineers to hot water. I may be wrong. Buchanan's work, published in 1810, strongly advocated steam as against hot water, and I think Tredgold agreed with that. I think the engineers in 1808 were strongly in favor of vapor or steam as against hot water. But towards the middle of the century that all changed, and illustrated the change in public opinion and the trend in Europe generally.

I think myself that Professor Carpenter in the title of the paper, "European methods of heating fifty years ago," has made a mistake. He might have made it the general practice of the world. Our practice in this country is almost the same as in England—following the English practice—the men, largely mechanics, coming from England. It is really the heating art of the world fifty years ago that Professor Carpenter has covered in his paper.

Mr. Cary: Professor Carpenter has given us considerable food for thought.

Last evening, at our dinner, there was included in our assemblage many recognized authorities in the design and construction of steam and hot-water heating plants, and the knowledge that this Society possessed such gentlemen as members caused, in the excitement of the occasion, a considerable amount of self-praise and "bouquet throwing," but when we pause to consider this matter calmly, and endeavor to rationally answer the question, What has actually been accomplished by the work of this Society during the past eleven years of its existence? what answer can be given? What definite examples can be proffered?

There have been many good old designs and theories trotted out in new clothes perhaps, but, as Professor Carpenter has shown, many of these were known and applied forty or fifty years ago.

It would be both interesting and instructive to continue such investigations, and show the condition of the arts of heating and ventilation eleven years ago, and add to this a statement of accomplishments in these lines during the past eleven years, and then find what part of these recent accomplishments were due to the efforts of this Society.

Possibly the latter statements would be a disappointment to many of us.

Professor Carpenter's paper is full of interest, and I hope that he will favor us with another one of the same sort.

CXLI.

# TEST OF A STEAM-HEATING BOILER

BY R. C. CARPENTER,
Chairman, Committee on Tests.

During the past summer the writer had an opportunity of making two tests of a steam-heating boiler which are believed to be worthy of record in the archives of the Society. It is the duty of the Committee on Tests to make accurate determinations of the efficiency and capacity of apparatus which is in use for heating purposes, and also to record, in such form as to be readily consulted, the results of such tests. The Committee on Tests has been remiss in the fulfillment of the obligation imposed upon it, principally because of the lack of opportunity on the one hand and the lack of time and means on the other, and it is hoped that a report of this test may be acceptable to the Society. I am also free to state that I believe much good would result if the capacity and efficiency of heating boilers were frequently tested.

It was formerly believed that steam-heating boilers under the usual conditions of operation were much less economical than the ordinary type of power boilers, but from investigations which have been made it seems that the reverse is true and that a steam-heating boiler generating lower pressure steam and burning from 3 to 5 lbs. of coal per square foot of grate surface per hour with coal supplied at infrequent intervals, and only as needed to maintain the required pressure, is fully as economical as a steam-power boiler generating steam of considerable pressure and supplied with coal by an expert fireman at a rate varying from 15 to 25 lbs. per square foot per hour.

The boiler tested was of a sectional type consisting of nine vertical sections connected to each other top and bottom.

Two efficiency tests were made, each of which was conducted practically in accordance with the rules for boiler testing prescribed by the American Society of Mechanical Engineers; in the first test the coal burned per square foot of grate per hour

averaged 3.8 lbs.; in the second case, 5.2 lbs. Each test was conducted for 7.5 hours, which is a somewhat shorter period than is prescribed for the testing of large power boilers, but as the amount of coal burned in these tests was small, the relative errors are believed to be much less than usually occur in the testing of large boilers for a period of ten hours. The steam pressure was maintained at slightly less than 4 lbs. by gauge during each test.

All the quantities required for determining accurately the capacity and efficiency were measured with instruments which were carefully standardized. The moisture in the steam was determined by the author's separating calorimeter.

The coal used during each test was anthracite, stove size, as supplied by the D., L. & W. Coal Co. This was fired in each case principally during the first two hours of each test. The heating value and analysis of the coal is appended to the results, as determined by calorimeter and analysis; these show that the coal is of ordinary quality and such as would usually be obtained for heating purposes.

The economic results were equivalent in each test to an evaporation from and at 212 degrees, per pound of combustible, to a little over 10.25 lbs. of water, which result will compare very favorably with those which could be expected from power boilers with the same kind of coal.

During the test the steam was discharged into the atmosphere, no attempt was made to condense it and return the condensed water to the boiler. It is, however, quite important to express the results denoting the capacity of a steam-heating boiler in terms of the radiation which can be supplied. This may be done by multiplying the number of pounds of water actually evaporated from a temperature of 212 degrees into steam by the number of square feet of surface of average radiation that would be supplied per hour by one pound of steam. The average results of a large number of tests of cast-iron radiators indicate that somewhat less than one-quarter of a pound of steam is condensed per square foot per hour or that one pound would supply, under average conditions per hour, somewhat more than 4 square feet of radiating surface. In expressing the results of the test in radiation, it was assumed that the square feet of radiation surface would be equal to four times the weight of steam evaporated per hour.

Each test was started with clean grates, but with the water previously heated, and practically as prescribed as the standard method in the boiler-testing directions of the mechanical engineers. In starting the fire the amount of wood recorded in the results was barred; in calculating the heating value one pound of wood was taken as the equivalent of 0.4 pound of coal. At the end of each test all the unburned coal was weighed and credited to the heater.

Some little time after starting was needed to brighten evaporation up to the average; for that reason the results for capacity are given on the basis of the evaporation after the fire had been started for two hours, although the entire coal burned and water evaporated is considered in computing the efficiency.

The following table gives the data and results of the two tests referred to above in convenient form for reference:

## REPORT OF BOILER TEST.

| | | Aug. 25, 1904. | Aug. 26, 1904. |
|---|---|---|---|
| Duration of Trial, | Hours | 7.5 | |
| **DIMENSIONS.** | | | |
| Grate surface, length 49″, width 18″ | Sq. ft. | 6.2 | |
| Heating surface | Sq. ft. | 155.5 | |
| Superheating surface | Per cent. | 12 | |
| Height, chimney | Feet | 40 | |
| Area, chimney 16″ × 4″ | Sq. in. | 64 | |
| Ratio heating to grate surface | | 25 | |
| **PRESSURE.** | | | |
| Barometer | Inches mercury | 29.06 | 29.21 |
| Steam gauge | Pounds | 3.7 | 3.7 |
| Absolute steam pressure | " | 18.0 | 18.0 |
| Draft gauge, near damper | Inches water | .07 | .09 |
| **TEMPERATURE.** | | | |
| External air | Degrees F. | 85 | 65 |
| Boiler room | " | 95 | 78 |
| Escaping gases | | 320 | 318 |
| Feed water | Degrees F. | 68 | 68 |
| Steam | " | 222 | 222 |
| **FUEL.** | | | |
| Kind of coal | Anthracite | | |
| Locality | D. L. & W. | | |
| Size of coal | Stove | | |
| Total coal consumed | Pounds | 162.25 | 224 |
| Total wood | " | 38 | 44 |
| Moisture in coal | Per cent. | 0 | 0 |
| Equiv. dry coal consumed | Pounds | 177.5 | 241.6 |
| Total refuse, dry | " | 17.5 | 19.75 |
| " " " | Per cent. | 9.8 | 8.7 |
| (c) Combustible, total | Pounds | 160 | 221.8 |
| **PER HOUR.** | | | |
| Dry coal | Pounds | 23.7 | 32.2 |
| Combustible | " | 21.3 | 29.6 |
| Dry coal per sq. ft. of grate | " | 3.8 | 5.2 |
| Combustible per sq. ft. of grate | " | 3.46 | 4.78 |
| Quality of steam used | Per cent. | 95.3 | 97.4 |

### Total Water.

| | | | |
|---|---|---|---|
| Total weight water used | Pounds | 1,500 | 2,005 |
| Total evaporated, dry steam | " | 1,440 | 1,960 |
| Factor of evaporation | | 1.165 | 1.165 |
| Equiv. evap. from and at 212° | Pounds | 1,677 | 2,283 |

### Water Per Hour.

| | | | |
|---|---|---|---|
| Amount used | Pounds | 200 | 267 |
| Evaporated dry steam | " | 192 | 261 |
| Equiv. evap. from and at 212° | | 224 | 304.4 |

### Economic Evaporation.
(Per pound of fuel.)

| | | | |
|---|---|---|---|
| Actual, per lb. dry coal | Pounds | 8.11 | 8.11 |
| Equiv. from and at 212° (dry coal) | " | 9.45 | 9.45 |
| (Per pound of combustible.) | | | |
| Actual | Pounds | 9.00 | 8.88 |
| Equivalent from and at 212° | " | 10.48 | 10.28 |

### Horse Power.

| | | | |
|---|---|---|---|
| On basis 34½ lbs. equiv. evap. per hour | H. P. | 6.5 | 9.7 |

### Averages Per Hour Excepting First Two Hours.

| | | | |
|---|---|---|---|
| Water per hour | Pounds | 218.1 | 381 |
| Dry steam per hour | " | 207.4 | 371 |
| Equiv. from and at 212° | " | 242 | 432 |
| Equiv. radiation ordinary cast iron | Sq. ft. | 968 | 1,728 |

### Last Two Hours.

| | | |
|---|---|---|
| Water per hour | Pounds | 263.5 |
| Dry steam per hour | " | 251 |
| Equiv. evap. from and at 212° | " | 291.5 |
| Equiv. radiation | Sq. ft. | 1,166 |

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## RESULTS OF COAL ANALYSIS.

| | | As Received. |
|---|---|---|
| Moisture | Per cent. | 2.84 |
| Volatile matter | " | 9.53 |
| Fixed carbon | " | 77.25 |
| Ash | " | 10.38 |
| B. T. U. | Per pound | 12,485 |

# CXLII.

## TOPICAL DISCUSSIONS.

### TOPIC NO. I.

"The Relative Advantage of Low Pressure and Vacuum Systems for Small Work in Residences."

There being no discussion on Topic No. 1, President Harvey introduced

### TOPIC NO. 2.

"The Ventilation of Tunnels, Subways and Kindred Constructions."

### DISCUSSION.

Mr. Cary: The matter of ventilating tunnels and subways has come before the public, especially in New York, since we have had our subways charged with noxious gases, bad air, etc.

I was at one time connected with a tunnel investigation, which led to my designing a system for ventilating tunnels.

In July, 1901, during the Grand Jury's investigation of the nuisance existing in the Park Avenue tunnel between Fifty-sixth and Ninety-sixth Streets, in New York City, I was retained by the District Attorney of New York County as engineering expert on ventilation, and in my testimony before the Grand Jury, I described a system of ventilation which may prove interesting to this Society in the discussion of this topic.

The greater part of the Park Avenue tunnel (as it is called) might be considered more as a partial subway. It contains four tracks, the two outer ones being placed (during the greater part of the tunnel's length) in what is known as the side tunnels, while the other tracks are located in one "centre tunnel." The greater part of the centre tunnel has openings in its top, while the side tunnels are closed, excepting a series of archway openings in the top of the 20-inch dividing walls, separating them from the centre tunnel. Thus, a part of the steam, gases, smoke and cinders

escape through these openings into Park Avenue and become a nuisance, as they blow into the adjoining houses, as was testified by numerous witnesses.

Park Avenue is a broad street measuring about 96 feet in width from curb to curb. Through the centre of the avenue are located a series of parkways about 40 feet in width and slightly less than 200 feet in length, their ends, at the intersections of the crossing streets, being semi-circular. In the centre of the parkways the openings from the centre tunnels are located, while grass and shrubbery surround these openings, extending to the stone copings around their outer edge, and on these copings an ornamental iron fence is placed.

Over the four tracks running through this tunnel all the trains passing in and out of the Grand Central Depot are run. Between 500 and 600 trains pass through this tunnel every day, and at times there is but 50 seconds headway between trains. The average time required by trains to traverse the tunnel is about 3½ minutes when no stops are made and no delays encountered.

The condition of the atmosphere in the tunnel and that in the passenger cars passing through the tunnel were investigated by Dr. Cyrus Edson (formerly President of the New York Board of Health), Dr. Chas. A. Doremus, and by officers detailed for this purpose by the Board of Health, and Dr. Edson in his report made the following statements:

"In my opinion, the tunnel is the cause of a very serious public nuisance, affecting the health and comfort of a very large number of persons. Each car contains less than 5,000 cubic feet of air-space, and, therefore, allows only about 56 cubic feet of air for each person. In the case of the 'Black Hole' of Calcutta, 146 persons were thrown into a room the size of an eighteen-foot cube at eight o'clock in the evening. The room contained a door and two windows. The latter were open. Each man had about 38 cubic feet of air space, and yet by 11.15 all were dead but 26, most of whom later succumbed to fever. The only cause operating to this effect was the exhaustion of the oxygen of the air.

"On Tuesday, the 23d inst., I boarded the 5.45 P.M. train, which passes through the north-bound side tunnel, and the following observations were taken in car No. 1024, the temperature of the air at Forty-second Street being at the same time 68 degrees Fahrenheit. The temperature in the car at the station was

95 degrees, and within four minutes the car's temperature had risen to 103 degrees; while the humidity in the air in the car at departure was 70 per cent., it rapidly rose within four minutes to 81 per cent. The humidity at Forty-second Street, opposite the depot, before the departure of the train, was 62 per cent.

"On Wednesday, July 24, I made a number of observations of cars in transit through the tunnel. One was on the 12.15 P.M. train on the Harlem road. The temperature of the car at starting was 86.5 degrees. Within four minutes, during transit, it had risen to 91 degrees, and the humidity rose from 70 to 76 per cent. The air was very irritating and several persons were seized with coughing spells. On entering the tunnel my pulse was beating at the rate of 70 per minute. At the exit it had risen to 96 per minute.

"On the 5.03 train for Port Chester, on the New Haven road on July 25th, the temperature at starting was 82 degrees and on exit 93 degrees; percentage of humidity at starting 64, at exit, 98; the time of passing three and a half minutes. The car was lighted with oil-lamps, and though the seating capacity was for only fifty-two, there were sixty persons in it, giving less than fifty-six cubic feet of air-space to each one. On leaving the tunnel the windows were all opened, and within five minutes the temperature dropped to 79 degrees and the humidity to 60 per cent.

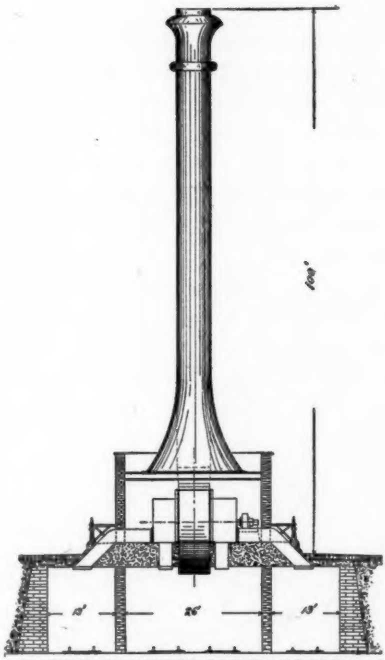
"The temperature in these cars during the warm weather varies from 85 degrees to 105 degrees. I have noted a temperature of 111 degrees, with a high percentage of humidity. The gases of combustion, plainly apparent to the senses while the cars are passing through the tunnel, are very poisonous, and in sufficient quantities will destroy animal life."

After a careful consideration of the existing conditions of nuisance and after studying various methods for its suppression, I arrived at the conclusion that mechanical ventilation was the most practical solution of the problem, which conclusion led me to submit the system described in this discussion, to accomplish the rapid removal of the greater part of the smoke, steam and noxious gases from the tunnel and at the same time providing for the introduction of an ample supply of fresh air into the tunnel.

It will be seen that I have made ample provisions to meet the objections offered by those residing on that part of Park Avenue occupied by this tunnel, by erecting chimneys over the outlets of

the fans used, thus discharging the steam and noxious gases at a considerable elevation above the roofs of these houses, instead of allowing them to issue at a level of the street (as at present).

With the steam and gases discharged above the roof level, the moving currents of air found there will carry them rapidly away and dilute them with the surrounding air, so as to cause no more local nuisance than is made with the many factory and domestic




SECTIONAL ELEVATION THROUGH TUNNEL SHOWING SUCTION DUCTS, FAN, AND STACK.

FIG. I.—VENTILATION OF TUNNELS.

chimneys about this city, and further, these discharged gases will be so diluted with the fresh air supplied to the tunnel that they will be, at the point of discharge, far less of a nuisance than the gases and steam now escaping from the openings over the centre tunnel.

In any system of ventilation it is a positive necessity for successful working to have the air enter and leave only at the points designed, and therefore it will be understood that it will be neces-

sary to entirely close the openings over the top of the central tunnel, now left open, and fresh air will then have a positive inflow through the intake ducts provided, while the foul atmosphere is positively discharged through the suction openings leading to the fans.

By referring to the accompanying illustrations, three sectional views of the tunnel will be seen, marked Figs. 1, 2 and 4, while Fig. 3 shows a plan view (looking down upon the parkways in the centre of Park Avenue).

In Fig. 1 is shown a sectional elevation at a point about midway between Sixty-first and Sixty-second Streets, where I proposed to place the suction fan and chimney. The fan casing will be seen above the middle of the centre tunnel. On each side of the fan casing will be seen inlet air boxes, which collect the foul air from the suction flues, and this air is drawn from these boxes into the fan casing, from whence it is discharged through the chimney into the outside air.

The suction flues (discharging into these inlet boxes) are four in number, the suction ends of which are placed directly over the centre of the four tracks shown, and as I proposed to place a fan in the centre of each block, it will be seen that the locomotive smoke stack will pass under one of the exhaust openings about every 250 feet.

This design includes all of the necessary flues and other parts entirely within the limits of the central parkway without encroaching upon the adjoining street. The chimney is constructed of steel plates. Its top is 100 feet above the street level and it is 7 feet in diameter.

I have designed the foundation of this chimney so as to form a house around the fan, and thus the parkway is robbed of the least possible amount of space. This chimney base (or fan house) could be built of neat architectural design, so as to avoid a disfiguring effect to Park Avenue.

Fig. 2 shows a longitudinal section of the tunnel from a point (at the left) just south of Sixty-first Street to a point (at the right) just south of Sixty-second Street, while the plan view just above it shows the same location (only looking down upon it).

The three broken parts shown in these two views are supposed to be filled in between the two central breaks, so that the illustrations include a length of somewhat more than a block

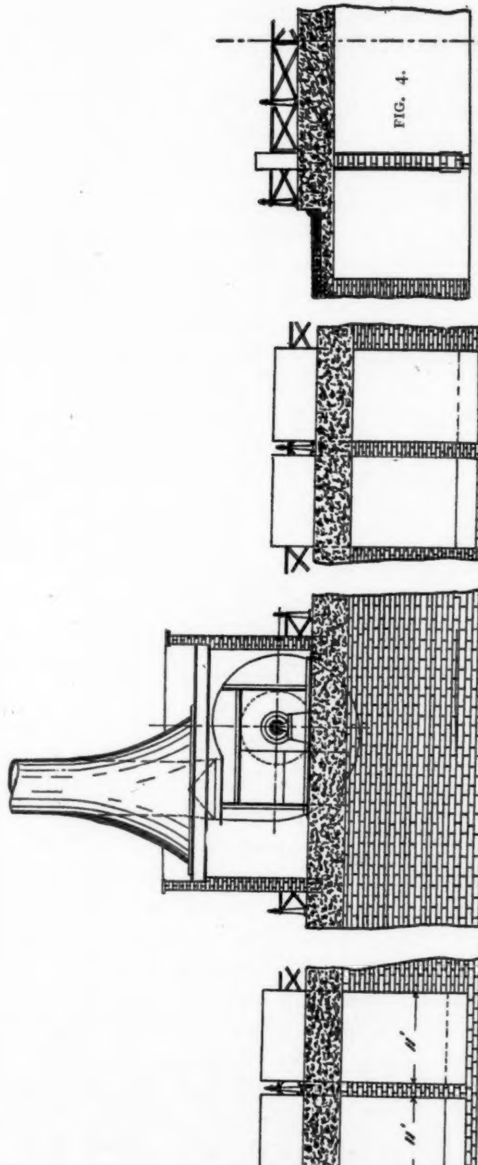
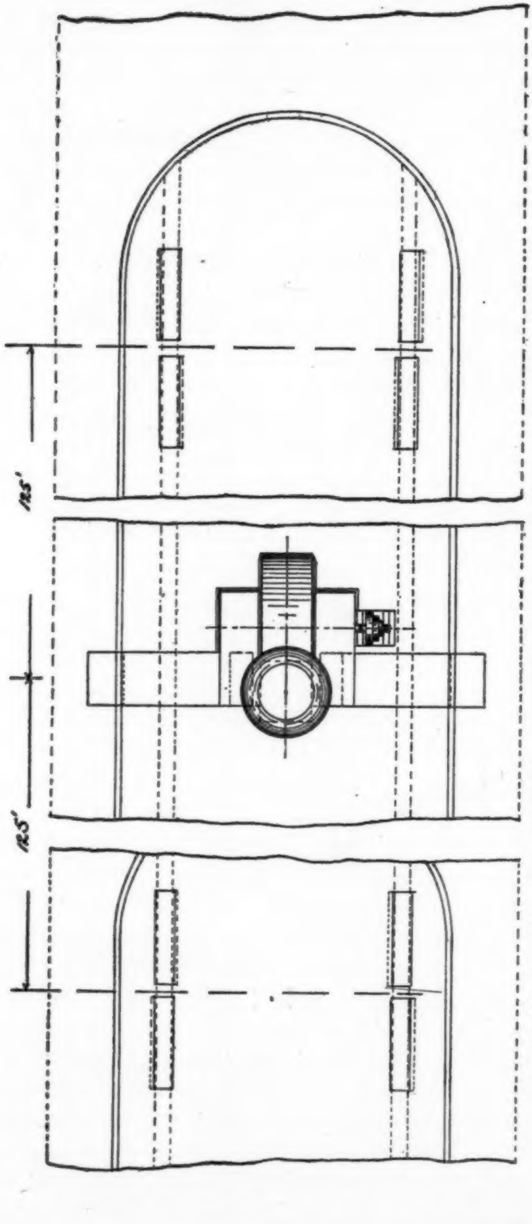



FIG. 2—VENTILATION OF TUNNELS.




PLAN SHOWING LOCATION OF INLET AIR DUCTS, SUCTION DUCTS, FAN AND STACK.

FIG. 3.

along Park Avenue, and thus they show the relative position of the inlet fresh-air pipes and the outlet flues connecting with the exhaust fan.

Four inlet fresh-air pipes are placed near the north end of each of the parkways, and with an average distance of 125 feet from the suction pipes of the fan. These fresh-air pipes drop to a point about 15 inches above the bottom of the tunnel (to prevent water entering their lower end) where they turn with an outlet towards the centre of the tunnel they supply with air. With the two inlet pipes placed side by side, one turns its lower end towards the centre tunnel, while its neighbor turns its lower end in the opposite direction, towards the side tunnel.

This is shown in the sectional view in Fig. 4. Owing to the extremely limited space in the tunnel, I arranged the fresh-air flues so as to fit into cuts made in the 20-inch wall separating the centre and side tunnels, and thus these flues extend but two inches into each tunnel beyond the surfaces of the present walls. Provision can easily be made to carry the roof beams of the tunnels on structural steel work where these flues are placed.

The upper ends of these fresh-air ducts extend about 7 feet above the level of the street (inside of the parkways), and I proposed to cover them with ventilators designed to keep out rain or snow.

To obtain a constant supply of fresh air as pure as that outside, when trains were passing the tunnel every fifty seconds, would require an unreasonably large outlay, and as air of such purity is not obtained in the best ventilated buildings, we should not expect to have it in this tunnel.

The amount of carbonic acid found in the air is generally taken in ventilation work as the index of its purity, and what is commonly considered as pure country air ordinarily averages about 4 parts per 10,000 of carbonic acid. Eight parts per 10,000 of carbonic acid is commonly considered as a standard of purity in the ventilation of buildings, while in this tunnel should the carbonic acid present occasionally reach 12 parts per 10,000, no serious inconvenience would be experienced by the passengers, and therefore taking twelve parts per 10,000 as a maximum allowance, with fans of sufficient capacity to exhaust all the air from this tunnel every two minutes, this result could be obtained.

I have included such a fan in my design, which is 12 feet in

diameter, to be run at 120 revolutions per minute and requiring 40 horse-power to operate it.

Forty fans of this size (necessary for the complete equipment of this tunnel) would therefore require 1,600 horse-power.

I proposed to operate all these fans by electric motors, connecting every alternate fan to a separate circuit, each of the two circuits being supplied with a current from separate engines and dynamos, so that in case anything should happen to the machinery connected to one circuit every second fan would still remain in operation.

I proposed that these important wires be placed in subways along the street, so as to guard against breakage due to wind, rain or sleet storms or the operations of the fire department, and I further provided duplicate reserve circuits connected with the Edison Illuminating Company's system, so as to guard against any possible accident or breakdown at the power house.

There are many mines now in operation depending entirely upon their mechanical ventilation for the lives of the miners, and the accidents due to stoppage in their ventilating system are unheard of in the modern well-equipped plants, and no mine has ever been so amply equipped with ventilating apparatus as this tunnel with the equipment offered in this design.

Should any one fan be stopped you will doubtless notice that there will still be left free openings to the atmosphere (through the ventilating exhaust ducts, the fan and the chimney). This will always be a free passage to the outside air whether the fans are running or not, and the warmer air in the tunnel will pass constantly up the chimney when the fans are not in operation, as the hot gases from a furnace pass up the chimneys they are connected to.

Returning now to the power required to operate these fans. We have seen above that 1,600 horse-power is required at the fan shafts. Allowing 27 per cent. for losses, we would therefore need a central power plant with engines delivering 2,200 horse-power to operate our fans, and this is only a little more than double the power developed by the locomotive drawing the Empire State Express when travelling at the rate of 70 miles an hour.

According to estimates, carefully prepared, the cost of installing this system with all fans, chimneys, exhaust and inlet air ducts,

including power house with its complete equipment, electrical installation, tunnel alterations, and everything exclusive of land required for power house, would be but $1,084,000, which is far below the cost of any other proposed remedy worthy of consideration.

This system of ventilating tunnels is by no means untried or new, as you can find the description of a similar method in the English paper, *Engineering,* of April 21, 1871, where Mr. Ramsbottom (a well-known English engineer) describes the mechanical ventilation of the Liverpool tunnel of the London and Northwestern Railway.

This tunnel is about a mile and a quarter long and has a sectional area of 430 square feet. The ventilation is effected by the use of a single fan 29 feet 4 inches in external diameter, and 7 feet 6 inches wide, placed in a shaft 175 feet high and 23 feet in diameter. With a speed of 45 revolutions per minute this fan cleared the tunnel of smoke and steam in about eight minutes, discharging about 431,000 cubic feet per minute.

The Park Avenue tunnel is about two miles long and has a total sectional area at the point shown in the accompanying drawing of 841 square feet.

The proposed ventilation, according to my design, is to be effected by 40 fans 12 feet in diameter and 6 feet in width, and these fans, with a speed of 120 revolutions per minute, will have a combined discharge capacity of 4,120,000 cubic feet per minute, almost ten times the capacity of the English fan, whereas the size of the Park Avenue tunnel is only about three times the size of the English tunnel.

Another most important difference between the Park Avenue tunnel and the English tunnel is that the fresh air supply had half the length of the tunnel to travel before reaching the discharge fan, while by my proposed method the fresh entering air is admitted every 250 feet, and the foul air also has a chance to escape every 250 feet.

By this system it will be seen that its first cost will be less than any change in motive power for hauling trains through the tunnel. Its cost of operation and maintenance will also be less and the time required for its complete installation will be *very much* less than any other change that has been suggested.

The only way to collect the air into one fan from a number of

different openings is to place a suction box outside the fan, and from the box you can carry a number of pipes in different directions and get good results, which is the plan I have used in this case.

Mr. Barwick: Did Mr. Cary note the effect of cold air on the exhaust steam from the engines, from the cylinders and from the smoke stack?

Mr. Cary: The steam exhausted from the engines goes through the stacks, which is usual with locomotive engines, for the purpose of inducing draft in the furnace. As far as the effect the cold air had upon it, the principal effect observed and pertinent to the case was during clear, dry days when the steam vapor would rise, as the air, of course, was heavier at that time, and pass out of the tunnel. When the air was highly charged with moisture the steam would hang down in the tunnel and lie down there as you will see a fog hanging over the surface of some lake. They could not get it out. The tunnel was filled with this vapor and it was difficult for the engineers to see a light twenty feet ahead of the locomotive because of it.

## TOPIC NO. 3.

"Grate and Heating Surface and their Relation to Space and Exposure in Furnace Heating."

Professor Carpenter: It strikes me that some years ago Mr. Chew took up this subject. He can probably give us more information on this subject than any one else here.

Mr. Chew: We did print some time ago relative proportions of different parts of heating systems in different parts of the United States, going as far West as Oregon, up in the northwestern part. I regret that I haven't them as closely in my mind as I would like to have in order to give now what we printed then. There does exist in furnace heating, as in any other thing in the mechanical line, some relative proportion of the various parts. One square inch of grate surface should be provided for about one square foot and a half—not far from that—of equivalent of glass surface, for furnace heating in residence work.

In the past I think the furnace men have gone too much on the rule of thumb, and haven't taken into consideration all the

important points. They have figured on the cubical contents of a building rather than the heat-losing power. And I am glad to see that there seems to be a movement in the direction of furnace men designing their work on the basis of equivalent glass surface, considering the exposure at the place where the heat is lost, instead of saying one square inch of area in the hot-air furnace pipe will heat twenty-five cubic feet of space in the northwest room, on the third floor, or thirty cubic feet in the southeast room, on the first floor, or thirty-five to forty cubic feet of space in the rooms with one side exposed. When it comes to heating large rooms, like churches, the relative proportions are much different. I cannot give the correct proportion there, but it will vary from one square inch of area in the hot-air pipe to something like eighty to one hundred cubic feet of space. These approximate figures I remember, but more than this I haven't at the present time. I forget what the relation was of the heating surface exposed in the furnace as compared with the grate.

There is one other point in connection with all this. You can say one inch of grate area is the equivalent of one and a half square feet of glass surface, but, if you don't know how much coal was burned, the type of construction, whether a direct draft furnace or an indirect draft furnace, the value of good construction is lost sight of. I am satisfied that with a good construction of furnace very much less coal will be burned with one square inch of grate area taking care of one square foot of glass surface —or something of that sort. However, from memory, and in the absence of information, I am not in a position to give more reliable figures.

Mr. Kent: Can you tell us if any furnace builders now publish a statement of the heating surfaces of furnaces—if there is any standard method by which any man can measure the heating surface and find out what it is?

Mr. Chew: I don't think I ever saw a catalogue giving the heating surface except one. As to the method of measuring, I think that is an approximation rather than a measurement.

Mr. Kent: In conversation with Mr. Richardson a year ago, I mentioned this trouble of getting certain rooms warm. He said: "You will have no trouble if you take a return flue from that room and carry it to your furnace." What surprised me about that statement was that I never heard it before. To-day

is the second time I have heard the idea. I would like to hear more on that subject. It strikes me as a reasonable and sensible idea. It is in this paper we have had to-day about return flues. I think it is going to be a great improvement in hot-air furnace heating.

In connection with this, I want to say I had in my house some years ago a first-rate heating furnace, which burned a great deal of coal and would not keep the house warm. A relative of mine had a house fully as much exposed and no better built. He burned less coal and had no trouble. His furnace was not quite as big as mine, and I came to the conclusion it was not altogether the furnace, but was the circulation of air through the pipes in the house. I then got a better system of circulation by putting a register in the hall, with a return pipe leading into the cold air duct through a Y branch and had better results.

Mr. Lyman: Let me say that method of returning air is very commonly employed in New York State. All through the northern section of New York it is a customary method, in connecting with the hot-air furnace, to take one, two, three or four return pipes from the rooms, especially the rooms hard to heat—against a northwest exposure, and carry them back to the furnace. Especially take a room that is tight, which has no fireplace or that has tightly closed doors, it is the commonly accepted method to take a return flue of almost the same size as the heat pipe and carry it back to the furnace, when the heating will be perfect.

The furnace manufacturers are as anxious to build high grade goods as are the boiler manufacturers. Further than that, the question of installation is just as important in warm-air work as in steam or hot water, and there are warm-air heating engineers taking as much pains to see that that work is as properly installed as are those who are installing hot water and steam heat.

Regarding the proper proportioning of a warm-air furnace, there come, I presume, to every manufacturer a great many suggestions regarding construction, which would increase the relative proportion between the heating surface and the grate surface, but you must bear in mind that anything which complicates an apparatus, even if placed on the market by a skilled engineer, immediately opens up a serious difficulty. The highest priced and most expensive furnaces made are the ones with which the

manufacturer has the most difficulty, simply because conditions of chimney draft, conditions of circulation and conditions of operation cause trouble. With the cheap work there is very little trouble or complaint. It is on the high grade work that the complaints come through the contractor back to the manufacturer.

Mr. O'Neil: I have had some experience along the lines just spoken of by the gentleman. I have found it almost impossible to get buildings perfectly tight. Indirect heating, steam and hot water are practically the same as with hot-air heating. You have to provide a circulation to get good results, and all engineers at the present time recognize that fact and provide some means for circulating the air, providing for each apparatus under different conditions. The idea of circulating air from the room back to the furnace is not a new one by any means. Fifteen or sixteen years ago they obtained very satisfactory results. In some instances, where I have found the furnace furnishing the heat not doing the work satisfactory, I have made a return back to the cold-air box, and obtained results whereby in some instances there would be a saving of five to ten per cent. in fuel.

In heating large halls, churches or theatres, and such buildings, I always provide for taking the air out of the room and returning it when no other means of ventilation is provided. I cannot see why there should be any fault found in that direction, because heating with direct radiation you are simply reheating the air in the rooms constantly.

I once had an experience in heating a large house with indirect steam, the contractor guaranteeing to keep every room in the house to 70 degrees when the temperature outside would be zero. When he came to test the apparatus the doors were closed, and he found he could not raise the temperature more than five or six degrees, but after opening the doors he finally raised it four or five degrees more. He afterwards removed some of the fireplaces in the halls and sitting-rooms, and they had no trouble at all in heating the building to the required temperature.

Mr. Bolton: It is notorious that if you go to a shoemaker you find his children with poor soles to their feet. If you go to a heating engineer's house, you would likely find a poor heater. I happen to occupy one of a row of houses, built exactly alike, and in which the heating furnaces were applied under the same conditions. It was the experience of my neighbors and myself that

we could not keep the houses warm. Last year I undertook to take care of the heater myself—and I imagine that is the best course a heating engineer can go through. I could not keep the house warm. I made an investigation and found the furnace put in was proportioned one square foot to seventy cubic feet of the contents of the house, and I found the hot-air pipes were placed as nearly horizontal as could be made. I dug a hole twenty inches deep and dropped the furnace into it and gave the pipes greater pitch, with the result that I didn't have to use anywhere near as much coal, and the house is heated with the greatest ease.

As regards the circulation of air from the interior of the house to the furnace, that is accomplished, in the domestic life of the engineer, by leaving the cellar open. The methods so far applied are likely to be imitated by all my neighbors.

Mr. Oldacre: Relative to the remarks of Mr. Kent, two years ago I took occasion to look over a heating plant in Canada at a time when the temperature was anywhere from 10 to 36 degrees below zero. The gentleman took me into the house and started in to explain how the apparatus was installed. The lady of the house was there at the time. She commenced by saying: "Don't you know, Mr. So-and-so, we have had these circulating pipes disconnected and we have had fresh-air ducts put in from outside, because it would not work until you did?" She claimed it would not heat the house at all with the circulating system.

I would like to ask this question of either Professor Carpenter or Mr. Kent: What would be the effect on the air of the rooms of a house as regards humidity, with the circulating system or with a system where the air is taken entirely from the outside; that is, would there be a higher relative humidity of the air, or a lower relative humidity of the air?

Mr. Kent: It would depend on the humidity out of doors. If the air in the house is of a certain humidity at 70 degrees Fahr., and that air is circulated around and around, the humidity would remain constant. Let some of that air out and take in air from out of doors that contains a smaller quantity of moisture per cubic foot or pound of air, then we would get less humidity. If the air out of doors contained more water per pound, we would have more humidity. It would depend on the conditions out of

doors. With the temperature at zero, it would carry little moisture. Conditions vary from time to time.

Mr. Oldacre: What I meant was, taking two plants under the same conditions—one the circulating system and the other with the air from the outside—with the same outside conditions as regards humidity of the air, and we will say no vapor pan.

Mr. Barron: The ordinary furnace, the ordinary heating boiler —commercial boiler, speaking generally—usually have but half the heating surface or grate surface that power boilers have. The average heating boiler has four feet of prime surface and sixteen feet of flue surface, twenty feet of surface to a foot of grate. The reason the furnace men and the heating boiler men won't disclose how much heating surface they give to a square foot of grate is, they know the surface is so inadequate they don't want to disclose it. We know heating boilers burn more coal in proportion than power boilers.

Mr. Oldacre: I take exception to what Mr. Barron has said in this regard. Most of the manufacturers I think are perfectly willing to give data, but it is a lot of work to measure up different boilers and furnaces when you have lots of them, and you don't want to stop and do it. I know that is a fact.

Mr. Bolton: It is hoped the manufacturers will make some arrangement by which the moisture can be added in some way other than the present water box. I have spoken to a gentleman who tried the experiment of introducing water at the register. He placed a pan there and had some pieces of string and cotton, a capillary arrangement to draw the water up across the line of air resultant. He found he evaporated ten times as much water into his house as he had with the previous arrangement of the water box, and he maintains he is better off. I explained to him if he introduced too much the paper would drop off the walls, the furniture would become unglued, and, possibly, his family would fall sick. He, however, maintains that as soon as this apparatus stops and he goes back to the water box as a supply of humidity he can taste the feeling in his mouth. (Laughter.)

Mr. Chew: Not that I think the President needs any defence whatever, but I will say I submitted this topic because there are fewer data existing in reference to the relative parts of hot-air furnace work than to any other system of heating extant. I think and know that the work of this Society to the present time

has led furnace men in all parts of the country to become more systematic. They are studying furnace work along scientific lines, and the Society is entitled to no small amount of credit for it. Yet the data which Professor Carpenter asked for a while ago, and which Professor Kent has been interested in getting, have not yet been furnished by members to the Society. I do not think there is any trouble except that furnace men have not been accustomed to measuring houses like steam men do. They say a ten-inch pipe will do for this room, etc. It has been done too much on the thumb rule plan, and a set of statistics is what the steam or hot-water man wants, to successfully take up hot-air heating. If he has not had experience with furnace work and with the meagre information available, he would have to work pretty hard to find the relative proportions.

The object of this topic is to eventually provide the archives of this Society with information that will enable the hot-water man and the steam man to go into the furnace business and make no mistake.

## TOPIC NO. 4.

"The Requirements of House-Heating Boilers Using Bituminous Coal."

Mr. Cary: The requirements of all house-heating boilers are the same whether they are operated with anthracite coal or with bituminous coal.

I have found in many cities of the West in the finer residential sections that the problem of burning bituminous coal economically, satisfactorily and without smoke has been dodged, and coke has been substituted as a fuel for the various fires in houses in order to prevent such neighborhoods from becoming fouled with smoke.

The house-heating boiler is quite a different proposition from that found in power-houses where a fireman is in constant attendance to frequently stoke and keep clean the fires under the boilers. In private houses the boilers must be attended frequently by the servants or else the so-called "furnace or handy man about the place," and as these employees have many other duties to perform, they cannot constantly stand over a fire and give it the attention required for the use of bituminous coal on ordinary grates, and, therefore, the bituminous coal house-heating boiler

should, in the same way as anthracite fires, be stoked and cleaned at infrequent intervals, and between such intervals such a fire should take care of itself in such a manner as will produce satisfactory results, both as to properly heating the house and with the combustion constantly continuing without the production of smoke.

As most of these present doubtless know there is no trouble in handling anthracite coal fires in a manner to meet the above requirements, as the fires can be cleaned in the morning and a sufficient amount of coal placed on the fire bed to supply sufficient heat until the middle of the day, when a second coaling will carry the fire through until night, at which time the fire may be cleaned and a sufficient amount of coal be again charged to continue the fire until the next morning, when it is cleaned and coaled.

The process of combustion with bituminous coal is altogether different from that of anthracite, as anthracite when heated to its ignition temperature will take fire and under proper conditions it will continue to burn *directly upon the grates* from the pure carbon (which is the principal constituent of anthracite coal) into carbonic acid or carbonic oxide. I wish to emphasize the fact that the combustion of this coal commences and is entirely completed directly upon the grates.

The combustion of bituminous coal instead of being a one-stage process, as I have just described, is a two-stage process. The coal consists not only of a certain amount of fixed carbon (the same as is contained in the anthracite), but it also contains a very considerable percentage of what is known as volatile matter, composed of gases, mostly combustible.

When bituminous coal is thown upon a hot fire bed the first thing to happen is the "distilling off" of the volatile matter which arises into the combustion chamber and is burned there as a gas while the fixed carbon remains behind upon the grate in the form of a coke, where it burns directly into carbonic acid and carbon monoxide, the same as the anthracite coal.

From what I have just said, it will be seen that not only must we provide a grate to burn our fixed carbon upon, but we must also provide a proper chamber above or beyond the grate in which to burn the gaseous matter which is "distilled off" from the coal. The gases composing this volatile matter are principally hydrocarbons, and it is an observed fact that the hydrogen will

unite with the air and burn at a lower temperature and with greater rapidity than the carbon, and if there is present only a sufficient amount of air to combine with the hydrogen and not enough to satisfy the carbon, which two gases compose the hydrocarbon gases, the hydrogen may alone be burned, the result of which combustion is a vapor of water or, more properly speaking, superheated steam, while the carbon will be thrown down in the small, troublesome flecks of soot, which will be carried away in the cloud of steam caused by the burning of hydrogen, and thus the color is given to the smoke.

The combustion of these hydrocarbon gases may either be suppressed or else may be made incomplete by chilling these volatile gases as they arise from the fuel bed below what is known as their ignition temperature. Every gas has a certain temperature at which it will ignite, take fire and burn, and below this temperature no combustion can take place. Again, if these gases be raised to their ignition temperature, then if they be suddenly chilled below the ignition temperature the combustion will be incomplete, and smoke and waste of fuel will follow.

In order to prevent the chilling of these gases below their ignition temperature before they are completely consumed, it has been the practice in large power plant boilers, where coal carrying a large percentage of volatile matter is used, to surround the furnace and combustion chamber with a mass of fire-brick, which fire-brick becomes highly heated during the process of combustion, and the gases as they rise from the coal are maintained at or above their ignition temperatures by the surrounding hot walls until the combustion is completed.

Besides these requirements, you will of course understand that it is necessary to provide means by which the oxygen contained in the air shall be brought in intimate contact with the volatile gases and thoroughly mixed with them, as if this intermixing is not properly done there will be a large percentage of the molecules of combustible gases carried out of the furnace and unconsumed.

The above consideration gives us a general idea of the different conditions presented by the use of the two grades of fuel, anthracite or coke on the one hand and bituminous on the other.

Now, to sum up the requirements of the general design of a house-heating boiler to handle bituminous coal satisfactorily, we

must in the first place have a boiler which is designed to allow a firing at infrequent intervals, say two or three times during the twenty-four hours.

Second.—This boiler must continue to burn this coal slowly and perfectly, so as to produce no smoke.

Third.—It must be designed in such a manner as to discharge its volatile gases from the furnace into a hot fire-brick mixing chamber before these gases have time to be chilled below their critical temperature of ignition.

Fourth.—This boiler must be provided with a runway in its combustion chamber of sufficient length to allow the gases to be completely consumed before they reach the chimney.

Fifth.—These burning gases must be brought in contact with the heating surfaces of the boiler, so as to be properly cooled to a low temperature before they are discharged into the flue outlet leading to the chimney.

Sixth.—The interior of the boiler must be so designed as to have no pockets or horizontal lodging places for soot and ashes, which will be carried from the fire along with the furnace gases and deposited upon it or in such objectionable spots, and it is well for me to call attention at this point to the fact that a coating of soot upon the heating surface will interfere very materially with the transfer of heat to the interior of the boiler, and, therefore, this must not be allowed to occur to any great extent.

Seventh.—The boiler should be so constructed as to not make it necessary to clean the boiler frequently.

The above requirements for a house-heating boiler pertain more especially to the requirements for combustion, but aside from these requirements, of course, the boiler parts must be simple and not easily put out of repair, its construction and design must be such as to stand the hard usage to which heating boilers handled by incompetent boiler tenders are subjected. It should be easily manipulated as far as stoking fuel is concerned, and also as regards means for getting rid of ash and clinkers. All parts should be readily accessible for cleaning and repairs, and it should be proportioned for the work to be done and capable of working to its fullest capacity with the highest economy.

There are other minor conditions which might be mentioned, but I will not attempt to continue this list further, as I believe I have pointed out the principal requirements.

## TOPIC NO. 6.

"Methods of Heating Large Bodies of Water for Public Baths and Industrial Purposes, by Steam or Otherwise."

Mr. Blackmore: I do not think that is a matter that needs a great deal of discussion. The heating of hot water is pretty much like hydraulics—it has gotten to be a fixed science.

It is unfortunate, however, that the simple laws which govern these things are not more appreciated among the architectural fraternity, for mistakes made in furnishing hot water are largely made through that source. It really is a very simple problem—the heating of water. It is so simple that most architects—and some of our profession—overlook it and provide inadequate boiler power. The heating of swimming pools and hot water for domestic purposes has grown to be a large business.

Some questions might be taken up and considered by the Committee on Standards, in the way of formulating approximate grate surface and heating surface for an apparatus for heating a given quantity of water, but I am not sure that is necessary. Among the manufacturers of heating apparatus, that subject seems to have been neglected so far as providing data for architects to go by, but since the profession of mechanical engineers has developed as it has within the last five or six years they are taking care of that part of the business in pretty good shape.

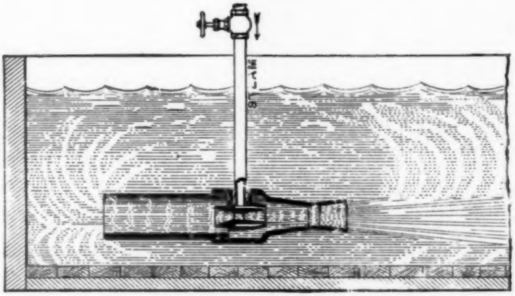
Mr. Kendrick: Of course, I do not know who the party was who proposed that Topic. If it was information he was seeking along these lines—of course, I don't wish to be egotistical or anything of the kind—but I refer him to the issue of March 6, 1897, of the *Engineering Record,* which covers a job installed by myself, which I think will give him details very thoroughly, and perhaps some information. I will state for the benefit of you, there were 70,200 gallons of water to be warmed.

Mr. Cary: In discussing Topical Question No. 6, I wish to present a very simple and effective apparatus for heating large bodies of water in public baths and tanks of all kinds.

It consists of a very simple ejector, which is here illustrated. The steam is introduced into the space enclosed by two annular rings, which are placed in the centre of this ejector, concentric to its outer circumference.

As the steam issues from the annular space, it forms a cylindrical steam jet, which steam rushes through the centre of the apparatus at a high velocity, and in doing so it draws with it a body of water through central and outside openings, inside and outside of the ring with the annular space, and in this way it projects the water for some distance beyond its mouth or opening into the tank, thus causing a violent circulation of water to take place. This arrangement enables the greatest quantity of liquid to be heated with practically no noise at all, as a thin sheet of steam comes in immediate contact with a large body of water, condensing it very rapidly.

In cases where water in a long tank is to be heated it is customary to screw a length of pipe into the inlet end of the water



NOISELESS WATER HEATER.

heater, so as to draw in the cold water near one extreme end of the tank and discharge it with the steam at the opposite end of the tank, and in this way, by the rapid circulation produced throughout the whole body of water, a very uniform temperature of the liquid is obtained in a very short space of time.

To illustrate this point, let us consider the apparatus having a ½-inch steam pipe connection and a 1½-inch cold water inlet. Such an instrument will raise the temperature of 100 gallons of water 50 degrees in 3 minutes.

By taking a larger heater having a 1-inch steam pipe connection and a 2½-inch cold water inlet, 100 gallons of water will be raised 50 degrees in temperature in one minute.

Mr. Kenrick: What pressure of steam?

Mr. Cary: Eighty pounds.

Mr. Kenrick: Were these placed on the inside of the tank?

Mr. Cary: Submerged entirely in water and a few inches above the bottom of the tank.

Mr. Kenrick: Isn't there a possibility of the bathers getting burned?

Mr. Cary: I have not applied it to a tank for that purpose.

## TOPIC NO. 9.

### "Proportion of Grate Surface Required for Different Fuels."

Mr. A. A. Cary: The combustible portion of anthracite coal consists practically of fixed carbon, which is burned directly upon the grates, while with bituminous coal, which may, for this illustration, be considered as consisting of fixed carbon and volatile matter, the former burning directly upon the grate bars (the same as the anthracite), while the volatile matter burns as a gas above or beyond the fire bed.

Thus, supposing we are able to burn anthracite coal at the rate of 15 pounds of fixed carbon per square foot of grate, and then, with the same draft and furnace conditions, we use bituminous coal consisting of 50 per cent. fixed carbon and 50 per cent. volatile matter. We should then (roughly speaking) be able to burn twice as much bituminous coal as we formerly burned when using anthracite, as no more fixed carbon would be burned per square foot of grate per hour with this amount of bituminous coal.

Of course, we must provide larger combustion chambers when using coals carrying volatile matter than when using anthracite, to provide for a proper combustion of the gaseous matter, and the combustion chamber must be properly designed to maintain the ignition temperature of the gases until they are entirely consumed.

I have not, thus far, taken into account the ash, which is a very important factor in the furnace, clogging the air passages through the fuel bed more and more as its percentage increases per pound of fixed carbon contained in the coal.

The President: We had a paper from Professor Carpenter, in which he spoke of four pounds of coal to each square foot of grate surface. Mr. Cary said he knew of 40 pounds being

burned to the square foot. It required ten times as much grate surface in the one case as the other.

In regard to bituminous coal, they are getting good results in ordinary boilers with from 15 to 30 pounds of coal per square foot of grate surface, per hour, and in locomotive practice over 100 pounds per square foot per hour. The proportion of grate doesn't depend on the quality altogether, but on the capacity for burning coal, and usually on the necessity you have for burning it. If you have only so much real estate to put grate surface on and have to burn so much coal, you will put in a forced draft. In house heating they burn four pounds of coal per square foot per hour. The question really cannot be answered as a general case, but each case has to be considered by itself.

I will say I had occasion to design a furnace recently for burning lignite in Texas. I wanted as much surface as I could get, twice as much as the ordinary tubular boiler has, and also shaking grates to be able to handle the ashes. I am sorry to say the furnace was never tested, but I hope to hear of its being tested before long.

## TOPIC NO. 10.

"The Extension of the Work of the Society in Special Fields."

Mr. Barron: My suggestion is this: That we have certain sessions which will in a measure be power sessions. That would attract power engineers to the Society. I think our attitude of keeping exclusively to our own field is right. I think power questions legitimately come into heating and ventilating. We have a number of engineers among our members who are experts in power work. There is this about it, the heating engineer doesn't care to join any other engineering society. He comes in here and pays his dues to the Society, and for that small sum is entitled to have that particular question being discussed. I do not think by going outside our field we can increase the usefulness and strength of our Society. Practical men, heating and ventilating engineers, as well as power engineers and consulting engineers, will be attracted to us, knowing such questions can be brought forward here as well as in other societies.

Mr. Chew: That Topic was suggested with the idea of securing the attention of men identified with central station heating systems. The engineer at a power station is a power engineer and a heating engineer in another sense.

Mr. Barron: If you will allow me, I want to say a few words more. We have to draw the line somewhere. We have drawn the line closely and certain questions have been excluded. I have thought we could attract a great many sanitary engineers.

If we had a session where we discussed sanitary subjects and their relation to heating and ventilating, it would be a good thing. We have members who are sanitary engineers, and are interested, and we might increase the membership that way.

The President: I think the Society could take up bacteriology so far as it refers to heating and ventilating. If we can kill bacteria by heating and ventilating, then that problem belongs in our Society. Anything belongs to our Society that comes in line with heating and ventilating. If an engineer desires a condenser for a Corliss engine or something of that kind, he should go to the Mechanical Engineers' Society and not here. It is well to concentrate our minds on one thing. We have a right to take up any science so far as it bears on our work, but not so far as it bears outside.

Mr. Quay: You say draw the line, but the question is, we have to have steam in buildings, and we have to consider the kind of boiler. It seems to me we should not go outside our legitimate line. This Topic about boilers I do not think it is necessary to discuss.

The President: I do not think we have made any rule on the subject. A member presents a paper and the publication committee accepts the paper because it is short of papers. I do not think any rule has been drawn nor is likely to be drawn very soon.

## TOPIC NO. 11.

"The Increased Efficiency of Heating Apparatus Using a Fan."

The President: In one of the volumes of our Proceedings there is an account of a saloon keeper who added a little electric fan—blower—along-side the radiator, and made an efficient ventilating system. There is no question at all about increasing

the efficiency of a heating coil or an apparatus of any kind by using a fan. But perhaps we can have some additional information that will add to our reports on that subject.

Mr. Quay: I had a little experience in that line with a small entrance to a dry goods store. By putting up a fan—a small fan—to blow the air from the register into the entrance, we got good results. The radiator could not possibly have heated the vestibule without the use of the fan.

Professor Carpenter: I made a number of tests, showing the amount of heat given off from a radiating surface due to increase in the velocity of the air moving over it. I found that the heat transmission varied with the velocity and averaged much more when the fan was used than when it was not used. (See fourth edition of "Heating and Ventilation.")

The President: I would like to ask Professor Carpenter if he says that a heating surface will give out 250 B. T. U. per sq. ft. of radiating surface, per hour, at a temperature of 70 degrees, or something like that without a fan?

Professor Carpenter: I do. Without a fan and with cast-iron radiating surface. About three to five times that when a fan is used.

The President: If you use a blast you might double it, or use a stronger blast up to five times that.

Professor Carpenter: That is the idea; yes.

## TOPIC NO. 12.

### "The Attitude of Engineers to the Society."

Secretary Mackay: I think that is a thing that will work out its own salvation. When this Society was first organized there were men looked upon as ideals in this profession. We went to see them, as suggested, and they said, in the first place, there was no place for this Society at all; it was fully covered by the mechanical engineers and others, and they would not come to us. We suggested that some come in and we would make them officers, and held out all sorts of inducements, but they kept away. I think the only thing we can do is to keep on along the same lines and make our Society the society of heating and ventilating engineers of the world, then those on the

outside will want to come in, no matter how big they are in their own opinion or the opinion of others. If we keep on increasing in membership, there will be a time when the man who is outside of our ranks, studying our profession, will want to be with us and of us.

Mr. Quay: This meeting is an indication of it. I am happily surprised to see the size of the Society and the interest taken. I cannot express my appreciation of the Society. Being interested from the start, I feel that the Society is doing a noble work. We want to make it so interesting and so strong that outside people will want to belong.

Mr. Barron: Mr. Mackay has expressed the views of all our membership, that when we become of value to the engineers outside they will come in. That question will settle itself. We should not make any effort to change from our present attitude. Last night, when looking around among the gentlemen at the dinner, I thought it was truly a representative gathering of heating and ventilating engineers. I say an engineer should be an authority in his line of work and should be a progressive man; in other words, a full-fledged and valuable citizen. There were at least ten or twenty men of that type, as high a type of citizen as anywhere in the civilized world. I don't think we need to change our attitude. The other gentlemen will change their attitude in a short while.

The President: I think there is a class of men in this country whom it is most desirable that the Society should get than these big heating and ventilating engineers who have held themselves aloof from us, and that is the young men, some of whom I saw last night at the meeting and others this morning, the young men of twenty-five to thirty-five years of age who are actively engaged in studying the profession with heating and ventilating concerns, many of them technical graduates. They are the men who are going to make the Society for the next ten or twenty years. They will come in in larger numbers. The old men are few and some will die before long, and these other men are going to be the real, good members of the Society. I hope each of you will try to bring in a number of this kind. I met one young man to-day, and said to him: "I would like to appoint you on a committee." He said: "I am not a member." I said: "It is high time you were." That is the kind of men we ought to get

in, young, active men, willing to debate and read papers and work on committees.

### TOPIC NO. 13.

#### "Indoor Humidity."

Mr. Feldman: Dr. Henry Mitchell Smith read a paper before a Brooklyn Medical Society on "Indoor Humidity." He has conducted a series of tests with reference to humidity and temperature, and a few extracts from that paper giving results of observations would be of interest in connection with the discussion on "Humidity" of yesterday.

Mr. Feldman read the following:

> The proceeedings of the convention of Weather Bureau Officials, held at Omaha, in 1898, contains a paper entitled "Atmospheric Moisture and Artificial Heating," by W. M. Wilson, of Milwaukee, who found that in buildings heated by steam and hot water, with an average temperature of 72 degrees, the relative humidity was 28 per cent., while with furnace heating it was as low as 24 per cent. We are principally interested, however, in the average outdoor relative humidity of New York City, where indoor records were taken, and I shall give only that of the months of October to April, inclusive: October, 73.9 per cent.; November, 74.8 per cent.; December, 73.6 per cent.; January, 75.2 per cent.; February, 73.6 per cent.; March, 71.1 per cent.; April, 67.8 per cent.
>
> The point to be emphasized is that every time we step out of our houses during the winter season we pass from an atmosphere with a relative humidity of about 30 per cent. into one with a relative humidity of, on an average, 70 per cent. Such a sharp and violent contrast must be productive of harm, particularly to the delicate mucous membranes of the upper air-passages.
>
> The overheating of our houses has been accepted as a prominent cause of catarrh, but I am confident that the low relative humidity, and consequently the large saturation deficit of the aqueous vapor in the atmosphere of our rooms in winter, is much more important than is the overheating in itself, and it may be doubted whether the so-

called damp climate of the sea-coast or the shores of large inland lakes is in itself so responsible for the above diseases as has been generally supposed. Moreover, at New York and along the Atlantic coast the prevailing winds during cold periods are usually from the north or northwest, having passed over a dry, frozen area which has presented little opportunity for the air to take up moisture. At such times the temperature of the air indoors is allowed to become as high as 76 degrees to 78 degrees in order to feel comfortably warm. Records from steam-heated apartments show that the relative humidity was sometimes as low as 25 per cent. with a temperature of 78 degrees, during a period of very cool weather in January, 1902. The high temperature is necessitated by the chilling of the body by the increased evaporation, evaporation being essentially a cooling process.

The winter of 1902 and 1903 was occupied in taking records and observations in rooms in which an experimental moistening apparatus was attached to a radiator. The mechanism was such that the control of the temperature and of the moisture were independent, a most important point, and observations were made at different temperatures and with varying percentages of humidity.

These tests were most instructive. In the first place it was observed that with a proper percentage of moisture 70 degrees Fahr. was comfortably hot, 68 degrees Fahr. warm and 65 degrees comfortable. By proper percentage of moisture is meant one which is never below 50 per cent. or above 70 per cent.—average about 60 per cent.

It was determined by repeated experiments that a temperature of from 65 degrees to 68 degrees and a relative humidity of 60 per cent. produced the most comfortable conditions, which were in marked contrast to a temperature of 72 degrees Fahr. with a relative humidity of 30 per cent. The former felt warm and balmy, the latter, notwithstanding the higher temperature, chilly and dry, and the slightest motion of the air suggested a search for the source of suspected draughts.

It was satisfactorily proven that one may live during the coldest weather with perfect comfort in a room at 65

degrees Fahr. where the relative humidity is kept at about 60 per cent.

During the experiments upon the sensations produced by different percentages of saturation, and in order to obtain the opinions of persons having no knowledge of the existing conditions, one room was equipped with a moistening apparatus and the temperature kept at 65 degrees to 68 degrees, with a relative humidity of about 60 per cent.* An adjoining room, without a moistening apparatus and heated by an ordinary steam radiator, had an average temperature of 72 degrees to 74 degrees, with a relative humidity of 30 per cent. In every instance, and without at all knowing what the temperatures were in the two rooms, the opinion was unhesitatingly expressed that the first room was several degrees warmer than the second.

Mr. Feldman: I move that Dr. Henry Mitchell Smith of Brooklyn be invited to present a paper giving the results of his experiments to the Society at some future meeting. I think we have had very little matter in our Proceedings relating to humidity.

The motion being duly seconded, was agreed to.

The President: We are very deficient as to facts bearing on humidity in relation to heating and ventilating. We have little literature on the subject of what constitutes good ventilation, and little on the subject of humidity that we can place dependence on. One question in regard to humidity we would like to know something about. Why is it when an Englishman comes to this country he complains of our overheated rooms, and when an American goes to England he complains of how chilly it is? Something in the nervous condition of the people, I think. A room feeling comfortable to an American is considered hot by the Englishman, and *vice versâ*.

Mr. Oldacre: Referring to Mr. Feldman's remarks, there is a work published in Germany—"Theory and Practice of Heating and Ventilating"—that gives the opinions of forty different authorities on the questions of humidity—German opinions, English and American opinions. Also, in Professor Reitochel's address on ventilation, quite a number of opinions are given on humidity. If you will go over that you will find the ideas of the different people vary, that there should be a relative humidity

of 15 per cent. up to 80 per cent., in order that the atmosphere shall be wholesome and such as is fit to breathe. The average as given by Professor Reitochel is as high probably as about 40 or 45 per cent. of humidity.

Mr. Oldacre: Wolfert's address gives an exact reference to each work, date of publication, etc.

# TRANSACTIONS

OF THE

# SEMI-ANNUAL MEETING

Chicago, Ill., July 7th and 8th, 1905.

## CXLIII.

# THE AMERICAN SOCIETY

OF

# HEATING AND VENTILATING ENGINEERS.

### SEMI-ANNUAL MEETING,

Held at the Auditorium Hotel, Chicago, Ill., July 7th and 8th, 1905.

## PROCEEDINGS.

### FIRST SESSION.

Morning session, Friday, July 7, 1905, ten o'clock A.M.

The meeting was called to order by the Secretary.

Secretary Mackay: Gentlemen, we are unfortunate this morning in the absence of our President, Professor Kent, who has been detained in New York, and also in the absence of Mr. R. P. Bolton, our First Vice-President, and of Mr. C. B. J. Snyder, our Second Vice-President, who is engaged at the National Educational Association Meeting at Asbury Park, where he thought he could do the Society more good than being present with us, as he has to read a paper before that Association. Our Constitution provides that "in the absence of the President and both Vice-Presidents, the meeting shall elect a temporary presiding officer from the members present; the Secretary calling for a vote." The nominations for temporary chairman are now in order.

Mr. Chew: Mr. Secretary, I think at a meeting of this kind, in the West, that some Past President from the West should be elected to preside instead of electing some member from the general body. It would be supported thoroughly if we had the entire Eastern membership here.

As Past President Kinealy of St. Louis is here, I nominate him for chairman of this meeting.

The Secretary: Mr. Kinealy has the nomination. Are there any other names?

Mr. Folsom: I would like to nominate Mr. Harvey of Detroit.

Mr. Harvey declined in favor of Professor Kinealy, who was unanimously elected.

(Whereupon Professor Kinealy, having been declared chairman, took the chair, and the following proceedings were had.)

Professor Kinealy: Gentlemen, I thank you indeed for the honor you have conferred upon me. I hope I shall be able to perform the duties of chairman to your entire satisfaction. The first business of the meeting is the roll-call.

The Secretary: Before calling the roll, Mr. President, I would announce the names of the following gentlemen, who have been elected to membership in our Society since the last meeting:

| | | |
|---|---|---|
| George W. Barr, | Philadelphia, Pa., | Member. |
| R. C. Beverley, | Richmond, Va., | " |
| Geo. L. Bottum, | Kansas City, Mo., | " |
| Robt. H. Feltwell, | Philadelphia, Pa., | " |
| Chas. W. Fortune, | Galt, Ont., Canada, | " |
| Almon O. Jones, | Battle Creek, Mich., | " |
| Samuel R. Lewis, | Chicago, Ill., | " |
| Clarence C. Mulford, | Denver, Col., | " |
| W. S. Patterson, | Appleton, Wis., | " |
| John T. Sadler, | Elmira, N. Y., | " |
| George H. Stibbs, | New York, | " |
| Chas. D. Symms, | Sioux Falls, S. Dak., | " |
| George J. Tobin, | Plainfield, N. J., | " |
| Levi J. Wing, | New York, | " |
| Wm. A. Birdsall, | Newark, N. J., | Associate. |
| Fred'k W. Jennings, | Leicester, England, | " |

(The Secretary then called the roll.)

The Secretary: Mr. President, we have more than a quorum present.

The Chairman: The next business is the President's address, but, unfortunately, while the mantle of the President has fallen upon me, I find no address with the mantle, so that will have to

be put off until some later day. The next business is the reading of our papers.

The first paper is entitled "Residence heating by direct and indirect hot water," by E. F. Capron, member of the Society.

Mr. Capron then read the paper.

It was discussed by Messrs. Brennan, Widdicombe, J. Mackay, W. M. Mackay, Munroe, Morgan, Thompson, Larson, Harvey and Donnelly.

The Chairman: The next paper is entitled "Flow of air in metal pipes," by J. H. Kinealy, member of the Society.

The Chairman: This is my paper, and I will ask Mr. Harvey to please take the chair while I read the paper. (Mr. Harvey took the chair.)

Professor Kinealy then read an abstract of his paper.

It was discussed by Messrs. Donnelly, Stangland and Harvey.

(Mr. Kinealy then resumed the chair.)

The Chairman: The next business is the discussion of certain topics. Topic 1 is, "Can pipe size for risers and radiator connections of risers be reduced?" Will the gentleman who proposed this topic please lead in the discussion?

Mr. Chew: I think that the gentleman who proposed that topic is not present this morning. It would not be very plain without a little further explanation.

The topic was discussed by Messrs. Munroe, Gifford, Donnelly, Morgan and Secretary Mackay.

The Chairman: If there is no further discussion on this topic, we will proceed to the second topic: "Can the area of mains in overhead systems of hot-water heating be reduced with benefit?"

(No discussion.)

The Chairman: Well, the third topic: "Is the expansion in heating mains uniform in all sizes and at all temperatures?" Any discussion on this topic, gentlemen?

(No discussion.)

The Chairman: The fourth topic: "What is the best material for a gasket in a flange union for hot-water piping?"

The topic was discussed by Messrs. Harvey, Donnelly, Jewett, Chew and Secretary Mackay.

The Chairman: Any further discussion? If not, a motion to adjourn for luncheon will be in order.

(Meeting adjourned to two o'clock in the afternoon.)

## AFTERNOON SESSION.

Friday, July 7, 1905, two o'clock P.M.

The Chairman: Before proceeding with the regular order of business, the Secretary has a cablegram here which he will read.

The Secretary: This is from one of our English members, member of "The Heating and Ventilating Society of Great Britain." He cables from Trowbridge, England: "Hope you decide to hold united meeting in England next year. Haden."

The Chairman: It is for the Society to say whether or not it will take any action on this cablegram. If you don't want to go yourselves you can select a representative, and pay his expenses. No doubt we could induce him to go.

Proceeding now with the regular order of business, we have the first paper, entitled "Notes on the Design of Central-Station Hot-water Heating Systems," by Professor Hoffman, member of the Society.

Mr. Hoffman then presented his paper in abstract.

The Secretary read a written discussion by Mr. Barron, and the paper was further discussed by Messrs. Schott, Jewett, Harvey and Davis.

The Chairman: Any further discussion, gentlemen? As there is no further discussion on this paper, we will proceed to the next. This is a paper entitled "Drying by Steam, Hot Air and Waste Gases," by Mr. Hugh J. Barron, member of the Society. Mr. Barron is not here, and I will ask Mr. Chew to be kind enough to read his paper.

Mr. Chew then read Mr. Barron's paper.

It was discussed by Messrs. Bixby, Chew, Jewett, Davis, Widdicombe, Scott and Bailey.

Mr. Chairman: We will now proceed to the discussion of the subject of "The bill to provide for the ventilation of public buildings in Illinois."

Secretary Mackay: That bill was to be presented at the last session of the Legislature of the State of Illinois, and it was thought that as our Society would have its meeting in Chicago this summer, that it would be well to consider this bill as presented at the meeting of the State Legislature, but it was not acted upon. The bill is somewhat similar to other bills that have

been introduced in other States from time to time. I don't know that it is necessary to read it.

The Chairman: Can you just give us the plain features of it?

The Secretary: Well, it doesn't ask for quite as much as we succeeded in obtaining in New York, and Mr. Waters wonders how we happened to get what we did. I told him that it was the result of eight or nine years of hard work, with final success after repeated failure.

The Chairman: What does it ask for, how many cubic feet per minute?

The Secretary (reading): "Shall not be less than 30 cubic feet per minute for each person," etc. The bill is very similar to the one that was passed in New York State. I would say along these lines that our Vice-President, Mr. Snyder, superintendent of Buildings of the New York Schools, felt that he could do more good for this Society and the profession at large by presenting his paper before the National Educational Association, which is in session at Asbury Park to-day, than he could by being here. That is his reason for not being here with us. While he regretted it, he felt that in going before the National Educational Association of the United States and getting before them the laws that have been passed, and the necessity for such laws, he would be helping the profession more than he would by coming to Chicago and taking part in this meeting.

The Chairman: What is the name of his paper?

The Secretary: His paper is entitled "Needed Legislation in School Architecture."

Mr. Chew: Mr. President, I don't know how the rest of the members here feel on the reading of a law that has failed to pass. I think it is more reflection on the Legislature than it is on the people who presented the bill for their consideration. Although the people of Massachusetts have not yet succeeded in getting a statute law, that is of secondary importance, because they have had peculiar police regulations there, and they have had a man who had the courage and intelligence to provide regulations which the people of the State of Massachusetts have observed for several years, so that they are practically as well off as if they had a statute law. They had a man there who, during his lifetime, insisted on the regulations being observed strictly, and they got 30 cubic feet of air per pupil per minute. It took several years

of very hard work, eight or nine years, to get the law through the New York Legislature. The difficulty was that the legislators thought there was graft somewhere. Among legislators, in any industrial proposition, many of them think there must be graft in it for somebody. That means that the members of our Society in any State, not only in Illinois, must have a chat with the different representatives of their Legislature, whether they come from the city or from the country district, and explain the common-sense of the whole proposition. That is where the whole secret of success lies. Now, they have succeeded in getting a law in New York, New Jersey and in Pennsylvania. We want to tell the Illinois people that they must work for the same end. I think we ought to take some action as a Society that can be used by the Illinois members in presenting this matter to the Legislature next year, saying that the ideas of the American Society of Heating and Ventilating Engineers are so and so, and call attention to the fact that the progressive States of Massachusetts, New York, New Jersey and Pennsylvania have adopted those laws as laid down by the members of the Society, that they govern the practice in those States. Every State should have laws compelling school-houses to be properly ventilated. If these facts are presented to the Illinois Legislatures, I am satisfied that we could get some legislators to understand and work for the law. We may get ten members this year, and ten more the next year, and we will be making progress toward securing a law in Illinois. I am in favor of having the Society act on the proposed law, as it will give support and encouragement to the local men, the Illinois members who have the matter in charge, it will help them along in their work.

The Chairman: Any further discussion, gentlemen? You do not make that as a motion, do you?

Mr. Chew: No, sir. Possibly Mr. Waters can frame a motion and bring it up at a later session.

Mr. Davis: I move that the motion be laid over until to-morrow morning, until Mr. Waters is here, and then we can get his opinion on the subject.

(The motion was duly seconded and carried.)

The Chairman: We will now proceed to discuss the topics. Topic 5, "The Protection of Underground Piping." If the

gentleman who suggested this topic is present, I would like him to lead in the discussion.

(Mr. Donnelly then read Mr. Barron's written discussion.)

Mr. Chew: With your permission, I think I can occupy the Society beneficially for a few minutes. There was a committee appointed last January, consisting of Professor Kent, Mr. Oldacre, of Philadelphia, and myself, to collect data on hot-air furnace heating. With your permission, I can make a little report and occupy the time of the meeting for a short time.

At the January meeting we had the pleasure of listening to a very good paper on hot-air furnace heating, and a number of questions were asked. Unfortunately for the furnace-heating trade, the relative proportions and the sizes of the various parts of a furnace system have not been recorded or classified, neither have data been collected by which anybody can make a good classification; as a result, numerous questions were asked members of the Society identified with furnace heating as to the size of grates relative to the glass, etc., and as a result a motion was made that a committee be appointed to collect data on that subject. Professor Kent, who is chairman, is absent, and I have received a letter from him in which he says he is somewhat disappointed that the series of questions which were prepared were not better responded to by the members. Every member of the Society received a copy of those questions, and I would not be surprised to hear you say they gave you a headache. I don't blame you for not answering them all, but I would have been glad if you had answered one or two. But there is one member who has answered the questions very fully, and that is Mr. Wm. G. Snow, of Philadelphia, and he will be here later to speak for himself.

I said when we sent out those questions that it would be too many questions, and I would be in favor of having a shorter list, and more pointed questions of a different character; but I was otherwise occupied and could not contribute my share to that labor. Now what Professor Kent says to us is that he hopes I will ask you people to join in getting up a set of questions on hot water and steam heating. It is a little bit discouraging, in view of the few answers received to the questions on furnace heating. I believe I have said before at the meetings of this Society that the most valuable papers this Society can have pre-

sented to it are descriptions of and detailed workings of systems, such as Mr. Capron has presented. Those detailed descriptions are of immense value to men who are going to step into the same field, are more valuable than anything else you could present here; and that is the idea of wanting those questions answered, so that such friends as Professor Kent, Professor Kinealy, Professor Carpenter and Professor Hoffman can have the figures classified before them, and eventually give us a paper out of our own meat which would be better than we ourselves could prepare. That is what Professor Kent is after from the Society, and he asks to have you do your share. If anybody has not a copy of those questions, they can easily be had. When you go back home, dig up the questions and see if you cannot give us something out of them. Those questions apply to the furnace men particularly. Those questions were printed in the different trade papers, so that not only the members of this Society could contribute to the subject, but men who are not members of the Society. Mr. Charles G. Folsom is a pretty good hot-air furnace man, and should answer the questions. Mr. Oldacre will do something when he gets to it, and Professor Kent will also. And finally Mr. Chew will do something; if he don't it won't be because he don't want to.

The Chairman: This meeting stands adjourned until to-morrow morning, at 9.30 o'clock.

## MORNING SESSION.

Saturday, July 8, 1905. 9.30 A.M.

The Chairman: Before proceeding with the regular order of business, I will ask the Secretary to read a communication which we have here.

The Secretary: This is from the President of the Institution of Heating and Ventilating Engineers of London, England.

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS.

NELSON STREET, BRISTOL, June 27, 1905.

MR. W. M. MACKAY, SECRETARY,

*The American Society of Heating and Ventilating Engineers, New York.*

DEAR SIR: Referring to my previous letter I beg to state that my Council are very enthusiastic as to the idea of your Institution of Heating and Ventilating Engineers visiting England in 1906.

I should be glad if at your next meeting (which I understand is to be held in Chicago on July 7th and 8th) you would kindly bring the matter before your Society as to whether it is possible to arrange a joint Summer Meeting of our two Institutions in England.

As you are aware, we have just completed our Summer Meeting in Bristol, and enclosed herewith is a copy of our programme, also press cuttings and souvenir menu and book of tickets, which latter was got out in connection with our outing to Blagdon on June 21st, and which I thought you might like to see.

Directly I have the pleasure of receiving your reply to the proposed combined meeting of our Institutions, it is arranged that I shall forthwith call a Council Meeting, and that we promptly go into the matter of arrangements.

Our prospective President—Mr. W. N. Haden of Trowbridge—is, as you are aware, one of your members, and I have no doubt he will write you personally on the matter. On behalf of our members, allow me to say that nothing would be wanting on our part to make the proposed visit of your members to our country pleasurable, and you may be assured that we should greet you in a truly Masonic spirit.

Awaiting your reply, I beg to remain,

Yours respectfully,

GEORGE CRISPIN,
*President.*

The Chairman: Gentlemen, you have heard this communication. I think we ought to answer it, that some action should be taken. What action will you take?

Mr. Davis: I move that the matter be referred to our Board of Governors for answer.

The motion was duly seconded and carried.

The Chairman: Is there any gentleman who has anything he wishes to bring up before we proceed with the regular order of business?

Mr. Waters, of Milwaukee, addressed the meeting in favor of having the next semi-annual meeting held in Milwaukee, and read an invitation to visit that city.

The Chairman: Gentlemen, you have heard this communication read. We must answer that in some way. What will you do? Do you wish to express any preference to the Board of Directors, or do you wish simply to refer the matter to the Board without recommendation?

Mr. Hoffman: I move that the Secretary be instructed to reply to this letter, expressing the thanks of the Society for its receipt, and stating that the matter has been referred to the Board of Governors for its final decision.

The motion was duly seconded and carried.

The Chairman: Any other gentleman who wishes to bring forward before we proceed with the regular programme?

The Chairman: Taking up now the programme for the morning, taking the first paper, we will now have that. It is, "Possibilities in heating with hot air," by R. S. Thompson, member of the Society.

Mr. Thompson read the paper, and it was discussed by Professor Carpenter and Messrs. Donnelly, Chew, Stangland and Folsom.

The Chairman: The next paper is entitled "Sheet metal radiation," by H. W. Nowell, member of the Society.

The paper was discussed by Messrs. Jas. Mackay, Morgan, Carpenter and Donnelly.

The Chairman: Any further remarks? If not, we will now proceed to the topics of discussion, and under that head comes the discussion on the bill to provide for the ventilation of public buildings in Illinois. That discussion was laid over from yesterday afternoon until this morning. We will now take up that topic of the discussion of that bill. Mr. Waters, will you lead this discussion, please?

Mr. Waters (Chicago): I had a conversation with Mr. Mackay this morning relative to the matter, and believe there must have been some misapprehension about the bill. It was not presented to the Legislature. In fact, the major portion of it was the New York bill that was forwarded me by Mr. Mackay, and I eliminated the portion of that bill which would not be applicable to our city ordinance. The New York bill embraced certain features that are covered by our city ordinance, in the Building Department, which the State has nothing to do with. The proposed bill is simply a compilation of the New York bill, together with as much matter as I thought would be proper and could be taken up for one consideration. It was sent to every local member of our Society, together with a letter requesting that we have a meeting for the purpose of discussing the matter, and see where eliminations might be made or certain conditions taken up and discussed, but I regret to say that I received but three or four replies to my letter, and as a consequence nothing further has been done. If the local members see fit between now and the meeting of the next Legislature, which will be two years from last winter, to co-operate and take this matter up, formulate a

bill, work jointly together, and see our friends in both houses of the Legislature—that is absolutely necessary in order to have anything go through, whether it is based on merit or not. I think there are some things in the amended bill, and also some things in the New York bill, that could not be gotten through our Legislature. For that reason I think it would be well to discuss the matter, as there may be some members present now who might be able to offer some valuable suggestions along these lines; if so, they can be taken up and considered later on.

The Secretary: I have a copy of the bill, and, as I stated yesterday, it is almost a copy of our New York bill, with some points that could not be passed left out, and I think we as a Society ought to endorse Mr. Waters's efforts. He is one of the committee of the Society on compulsory legislation, and we ought to impress on our membership in Illinois the need and necessity of assisting the committee in this laudable effort. I can talk intelligently on the subject from the fact that I have in the past been a member of the Legislative Committee of the Society for a number of years, and was chairman of it for two years. Unfortunately, I, like Mr. Waters, was on the committee when we didn't meet with much success. We tried hard, and saw success almost within our grasp in several sessions of the New York State Legislature, and in the New Jersey Legislature, and in the Pennsylvania Legislature. We were congratulating ourselves that the work was done, that we had accomplished our purpose, when we found we had failed and that we had to do it over again. In New York State we introduced bill after bill for eight or nine years. Some of the bills were good, and some of them were poor in that they did not ask what we, as a Society, thought we ought to get, but we were glad to get them in the shape they were in the hopes of getting something on the statute books that would help us later on by amending it, and finally, largely through Mr. Snyder's efforts, and the efforts of the National Educational Association, who were interested, they took the matter up, at a meeting of the State Superintendents at Albany, and endorsed it and spoke to their State senators and legislators. I, as Secretary, was instructed to write a letter to every member in New York State, and ask him to influence as many State senators and members of the Legislature as he could, and something like seventy-three members were reached in that

way of our own membership, and we got replies from, I should say, fifty of them; and I also got replies from those members of the Legislature and senators whom our members had influenced, and it was finally put in the hands of a representative of the Legislature from a country district. We were advised in Albany that that was the proper thing to do if we wanted to get it through. We began to feel that our bill, which was a very strong one, was going to have the same fate as previous ones, when last April it was passed in both houses almost at the close of the Legislature.

Now in connection with Massachusetts, and in connection with this bill, I would say that Massachusetts started in on something that is very harmless in their bill. It has been said at this meeting and at previous meetings that Massachusetts had no law covering the ventilation of public school buildings, but that the district police have enforced this form No. 83; now by referring to the laws of the State of Massachusetts I find they tacked these district police laws on to a bill which reads, "Acts of 1894, Chapter 508, an act regulating the employment of labor." I quote from this chapter the following:

SEC. 40. Every public building and every schoolhouse shall be kept in a cleanly state and free from effluvia arising from any drain, privy or other nuisance, and shall be provided with a sufficient number of proper water closets, earth closets or privies for the reasonable use of the persons admitted to such public building or of the pupils attending such schoolhouse.

SEC. 41. Every public building and every schoolhouse shall be ventilated in such a proper manner that the air shall not become so exhausted as to be injurious to the health of the persons present therein. The provisions of this section and the preceding section shall be enforced by the inspection department of the district police.

SEC. 42. Whenever it appears to an inspector of factories and public buildings that further or different sanitary provisions or means of ventilation are required in any public building or schoolhouse, in order to conform to the requirements of this act, and that the same can be provided without incurring unreasonable expense, such inspector may issue a written order to the proper person or authority, directing such sanitary pro-

visions or means of ventilation to be provided, and they shall thereupon be provided, in accordance with such order, by the public authority, corporation or person having charge of, owning or leasing such public building or schoolhouse.

SEC. 43. Any school committee, public officer, corporation or person shall within four weeks after the receipt of an order from an inspector, as provided in the preceding section, provide the sanitary provisions or means of ventilation required thereby.

The Secretary: That is the Massachusetts law, the State law as far as it has gone for the last twenty years, and there is less to it than there is in our Pennsylvania law, and we are not any too proud of that. Now, district police form No. 83 reads as follows:

Form No. 83. District Police.

Department of Inspection of Factories,
Workshops and Public Buildings.
Office, State House, Boston.

In the ventilation of school buildings the many hundred examinations by the inspectors of this department have shown that the following requirements can be easily complied with:

1. That the apparatus will, with proper management, heat all the rooms, including the corridors, to 70 degrees F. in any weather.

2. That, with the rooms at 70 degrees and a difference of not less than 40 degrees between the temperature of the outside air and that of the air entering the room at the warm-air inlet, the apparatus will supply at least thirty cubic feet of air per minute for each scholar accommodated in the rooms.

3. That such supply of air will so circulate in the rooms that no uncomfortable draught will be felt, and that the difference in temperature between any two points on the breathing plane in the occupied portion of a room will not exceed 3 degrees.

4. That vitiated air in amount equal to the supply from the inlets will be removed through the vent ducts.

5. That the sanitary appliances will be so ventilated that no odors therefrom will be perceived in any portion of the building.

To secure the approval of this department of plans showing methods or systems of heating and ventilation, the above requirements must be guaranteed in the specifications accompanying the plans.

Approved: RUFUS R. WADE, Chief Instructor,
Inspector of Factories and Public Buildings.

The Secretary: I thought that those points ought to be brought out so as to give our members in Illinois the hope that something could be done here. Let them not get discouraged because of failure, because we have had failure after failure, and we still kept at it, and we finally reached success.

The Chairman: Is there any further discussion? We will consider this as a report of progress. It is, of course, to be earnestly hoped that the committee and Mr. Waters will continue their efforts. The next order of business is Topic No. 8, which is: "Are the benefits derived from large mains with branches in hot-air furnace systems sufficient to merit wider adoption." If the gentleman who sent this in is present, I should like for him to lead the discussion. There is a written communication that has been submitted.

The Secretary: Gentlemen, Mr. Skelleberg, of Iowa, who is not a member of the Society, suggested that topic by writing the Society and asking that if we could have a paper presented before the Society on the subject of large mains, or single pipes in hot-air heating. His letter was received too late to prepare the paper and get it before the committee in time to be printed with the other papers, and he was written to that effect, and suggested that we insert a topic in our programme. He writes under date of July 6th, as follows:

DUBUQUE, IOWA, July 6, 1905.

MR. W. M. MACKAY, SECRETARY,

*The American Society of Heating and Ventilating Engineers, Auditorium Hotel, Chicago, Ill.*

DEAR SIR: I regret at this last hour to tell you that I cannot accept your kind invitation to your meeting at Chicago on the 7th and 8th inst., as I had fully intended.

I will preserve your paper sent me, and will reply to same with a description of a large main system of hot-air heating, to be presented at the next Annual Meeting.

I notice on your programme Topic No. 8, "Are the benefits derived from large mains with branches in hot-air furnace systems sufficient to merit wider adoption?"

I answer, practical experience has proved to me that this is the ideal system, and to prove my claim will prepare two papers to be read at next meeting, showing where I changed two plants from individual piping to the large main system, using same furnaces and location of registers unchanged.

Thanking you for the kind invitation, I remain,

Very truly yours,

R. L. Spellerberg.

The Chairman: Any further discussions? If not, we will pass to the next topic. The next topic is "Vacuum systems of hot-water heating." If the gentleman who suggested that is present, we would like to have him lead the discussion.

Mr. Hoyt then discussed the topic.

The Chairman: Any further discussions? As there is no further discussion, we will now go to the next topic, No. 10. There being no further discussion, we will proceed to the next topic, "The production of wrought-iron screw nipples." That was suggested by Mr. Barron, who sends in a written discussion. Will you read it, please?

The Secretary: This is his discussion on the topic of nipples, by Mr. Hugh D. Barron, member of the Society.

Mr. Barron then discussed the topic.

The Chairman: There being no further discussion on this topic, I believe we have arrived at the end of our business. Now before we adjourn, is there anyone who has anything he wishes to bring before the Society? I think that we may congratulate ourselves upon the success of this Western meeting, and as a Western member I hope it will be repeated.

Mr. D. K. Munroe: I would like to have the Society pass a vote of thanks, on the part of our members, for the kindness and courtesy that the Chicago and Illinois members have shown us here in this city. We from the East feel very much gratified, and have enjoyed ourselves very much, and I want to express my pleasure for the good time I have had.

The Chairman: Gentlemen, that resolution needs no seconding. I think that should be a rising vote. All in favor of that please rise.

(Everybody arose.)

The Chairman: We extend our thanks to the members in

Chicago and Illinois. Are there any further resolutions?

The Secretary: Mr. President, before adjourning, I think it would be well to pass a resolution thanking the Press for their efforts in making a success of this meeting.

The Chair: All in favor of that motion signify it by saying "Aye."

(Motion carried.)

Mr. Strangland: I move we adjourn.

(Motion seconded and carried, and meeting adjourned.)

List of members and guests present at semi-annual meeting, July 7 and 8, 1905:

MEMBERS.

Allen, John K.
Brennan, John S.
Capron, Edmund F.
Carpenter, Prof. R. C.
Chew, Frank K.
Davidson, W. H. A.
Davis, James H.
Donnelly, Jas. A.
Driscoll, Wm. H.
Edgar, A. C.
Fielding, Howard H.
Folsom, Chas. G.
Graham, Joseph
Hale, John F.
Harvey, Andrew
Hoffman, Prof. J. D.
Hudson, P. S.
Kinealy, Prof. J. H.
Lewis, Samuel R.
Mackay, James
Mackay, Wm. M.
Munroe, E. K.
Neiler, Samuel G.
Nowell, H. W.
Patterson, W. S.
Robinson, H. A.
Scott, Geo. Welsby
Stangland, B. F.
Stockwell, W. R.
Thompson, R. S.
Walker, J. J.
Waters, T. J.
Widdicombe, R. A.

GUESTS.

Ainsworth, A. A.
Allen, E. P.
Arens, A. T.
Bailey, F. W. C.
Ball, Chas. B.
Bard, Geo. M.
Bassler, Edwin
Best, W. J.
Bishop, F. R.
Bixby, J. T., Jr.
Bonitz, Dudley
Boylston, John
Brady, B. W.
Brown, A. E.
Callon, H. C.
Casey, M. B.
Catlin, A. W.
Conine, H. V.
Cooke, D. I.
Crawford, E.
Cripps, A. G.
Curtis, W. W.
Davis, G. C.
Downe, Geo. E.
Drury, L. H.
Ebersole, Morris R.
Ellis, H. W.
Evers, Edw. A.
Folsom, C. R.
Foster, C. K.
Frost, N. E.
Gifford, Robt. L.
Gilmore, Frank
Grassler, E.
Graves, W. B.
Griffiths, P. L.
Herlov, Rasmus
Henning, F. H.
Hibbard, John D.
Hicks, M. B.
Hoffman, Geo. D.
Howell, S. S.
Hoyt, A. G.
Isertell, Henry G.
Jewett, F. N.
Johnson, W. L.
Junker, R. A.
Kauffman, Benjamin
Kauffman, Samuel
Ketchum, James T.
Larsen, L. A.
Lord, H. I.
Martin, J. H., Jr.
May, Edw. A.
McMaster, F.
Miller, J. J.
Morgan, D. F.
Moss, D.
Mott, M. H.
Munroe, Wm. S.
Murphy, Everett
Murphy, E. M.
Nistle, G. W.
Olson, J. H.
Ovist, C. L.
Pearce, W. H.

| | | |
|---|---|---|
| Philbreck, M. E. | Stark, E. A. | Watrous, R. B. |
| Pope, W. A. | Stark, F. J. | Widdicombe, W. |
| Rowell, H. B. | Stern, Daniel. | Williams, J. H. |
| Schott, W. H. | Swan, E. R. | Winslow, E. De F. |
| Sherriff, H. T. | Tratman, E. E. R. | Wray, R. T. |
| Small, John D. | Van Auken, B. E. | Younglove, E. H. |

## CXLIV.

# RESIDENCE HEATING BY DIRECT AND INDIRECT HOT WATER.

BY E. F. CAPRON.

During the past ten years the writer has installed a number of hot-water heating plants, using both direct and indirect radiation, and the results obtained have been very satisfactory, both with the overhead and the up-feed systems of circulation.

The heating apparatus described in this paper was installed in a three-story and basement brick residence, having exposure on all sides, with no protection from surrounding buildings.

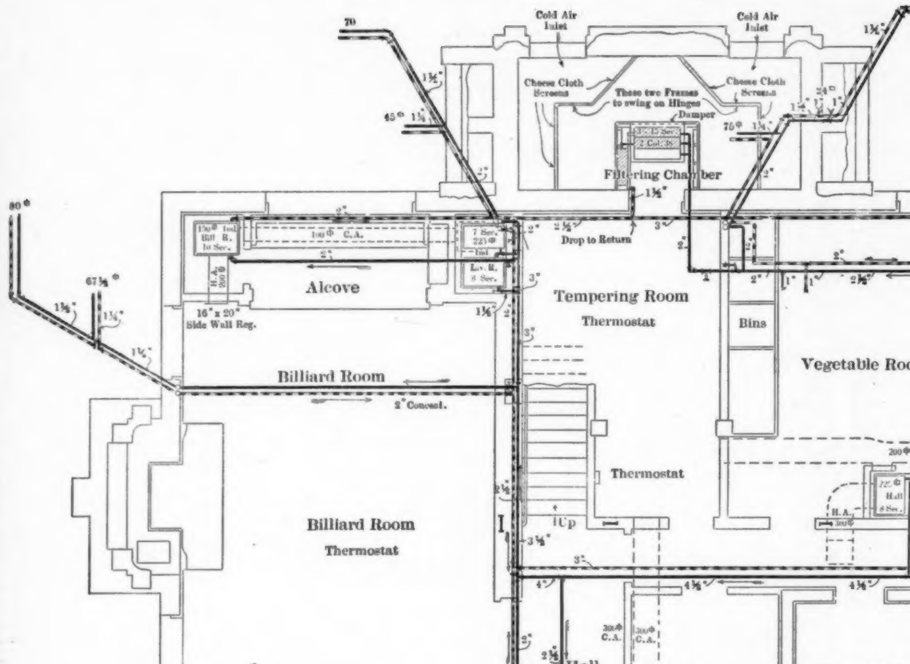
The cubic contents of the building is 98,304 cu. ft., wall exposure 7,182 sq. ft., glass area 1,416 sq. ft., and it is heated by 2,518 sq. ft. of direct and 1,200 sq. ft. of indirect surface, with 285 sq. ft. in the tempering chamber.

There are two boilers of the locomotive fire-box type, brick setting, each containing 279 sq. ft. heating surface and 9.2 sq. ft. grate area, one boiler being used in ordinary winter weather (15 degrees above zero). The automatic system of heat regulation controls the temperature in a number of rooms and also controls the draught to boilers.

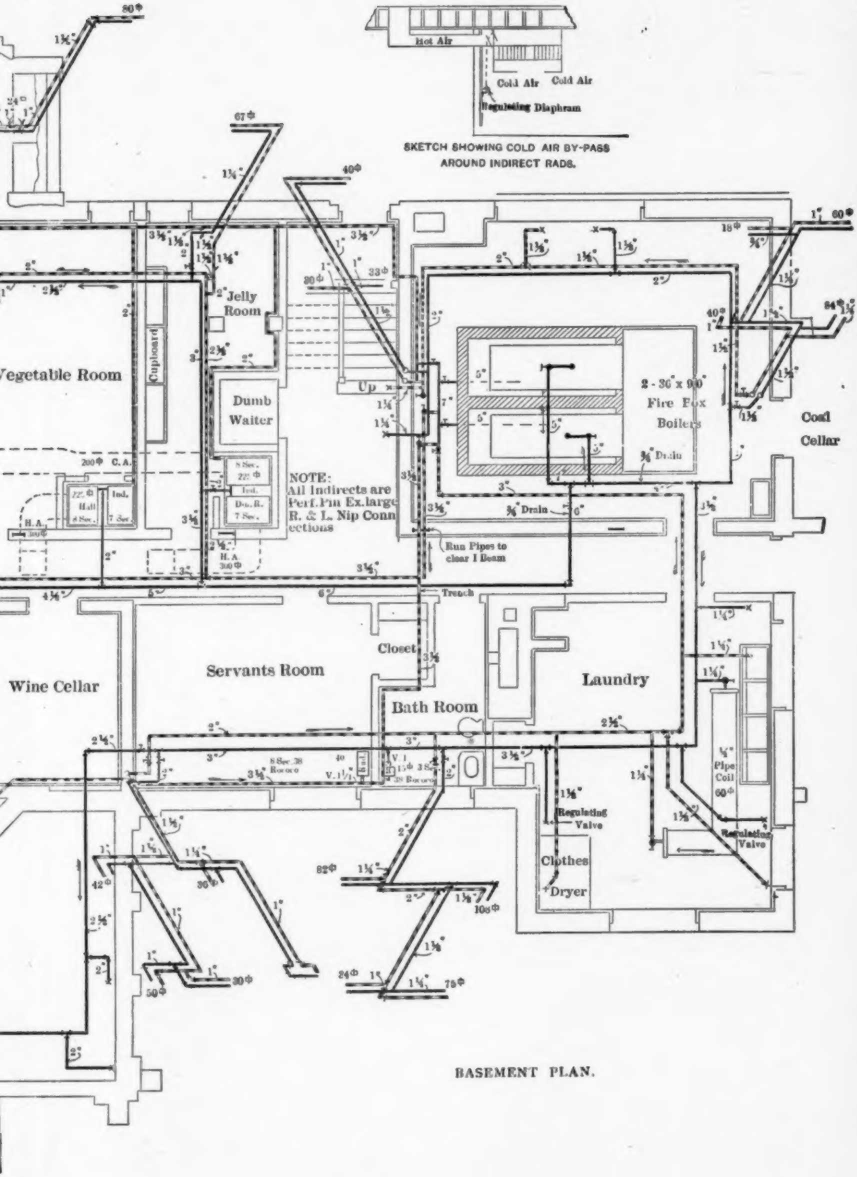
The system of piping is what is called "up-feed" except in the sun-porch, which is one-pipe. All piping is concealed and covered. Each pair of risers has controlling valves with drip valve for draining, and each stack of indirects is treated in the same manner.

The air for indirect radiators enters the building through two windows, having shutters which are easily adjusted, passes through cheese-cloth screens and through tempering radiators into a main cold-air room, from which room galvanized iron ducts carry the air to the various radiators.

There is a by-pass damper under the tempering radiators, controlled automatically, the thermostat controlling same being located in cold-air room.



Cold Air Inlet
Cold Air Inlet
Cheese Cloth Screens
These two Frames to swing on Hinges
Damper
Filtering Chamber
Drop to Return
Tempering Room
Thermostat
Alcove
16" x 20" Side Wall Reg.
Billiard Room
2" Conceal.
Billiard Room
Thermostat
Thermostat
Up
Bins
Vegetable Roo
Hall
Store Room
Wine Cellar
Side Wall Reg. 16" x 20"
Gate V. in Drop




BASEMENT PLAN.

Each individual stack of indirect radiators has a by-pass damper, allowing tempered air being admitted to the rooms when the temperature rises to 70 degrees. The rooms heated by indirect radiation are ventilated by means of fireplaces.

The house has been satisfactorily heated, but the plant is somewhat complicated for the ordinary house man to operate and obtain the best results.

During the month of February of this year the writer made a test in the operation of the plant, the results of which are given below:

FEBRUARY 15, 1905.

| Temperature taken at | 7 A.M. | 9 A.M. | 11 A.M. | 1 P.M. | 3 P.M. | 9 P.M. |
|---|---|---|---|---|---|---|
| | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* |
| Outside | —8 | —3 | 8 | 9 | 10 | —2 |
| Water supply | 180 | 180 | 176 | 170 | 168 | 160 |
| Water return | 150 | 160 | 154 | 140 | 144 | 138 |
| Cold-air room | 44 | 50 | 52 | 40 | 40 | 40 |
| Servants' dining room | 70 | 70 | 70 | 70 | 70 | 70 |
| Parlor | 76 | 76 | 76 | 76 | 78 | 76 |
| Billiard room * | 54 | 54 | 54 | 57 | 58 | 60 |
| Conservatory | 60 | 66 | 68 | 64 | 67 | 67 |
| Reception hall | 70 | 70 | 74 | 76 | 77 | 76 |
| Amt. fuel consumed during day | 910 pounds anthracite coal. | | | | | |

* One register closed.

FEBRUARY 19, 1905.

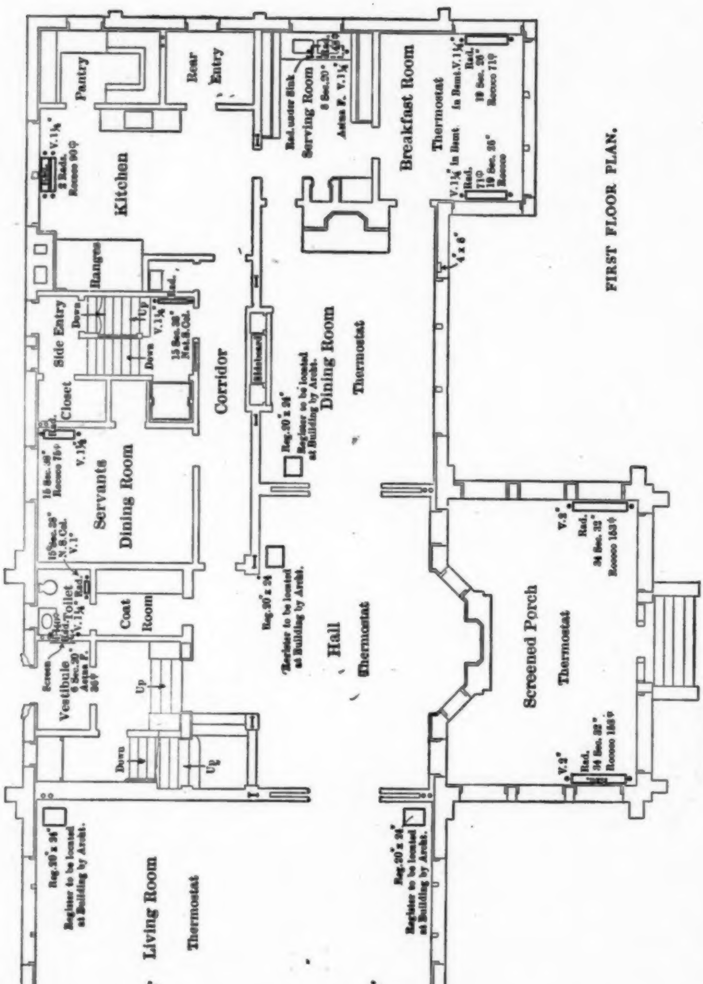
| Temperature taken at | 7 A.M. | 9 A.M. | 11 A.M. | 1 P.M. | 3 P.M. | 9 P.M. |
|---|---|---|---|---|---|---|
| | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* |
| Outside | 16 | 24 | 35 | 36 | 36 | 32 |
| Water supply | 130 | 156 | 165 | 172 | 170 | 156 |
| Water return | 120 | 135 | 140 | 150 | 148 | 140 |
| Cold-air room | 46 | 48 | 56 | 58 | 60 | 58 |
| Servants' dining room | 70 | 70 | 68 | 70 | 70 | 70 |
| Parlor | 68 | 70 | 68 | 70 | 72 | 72 |
| Billiard room * | 62 | 62 | 64 | 66 | 58 | 68 |
| Conservatory | 60 | 64 | 68 | 69 | 68 | 68 |
| Reception hall | 70 | 70 | 72 | 72 | 72 | 72 |
| Amt. fuel consumed during day | 627 pounds anthracite coal. | | | | | |

* One register closed.

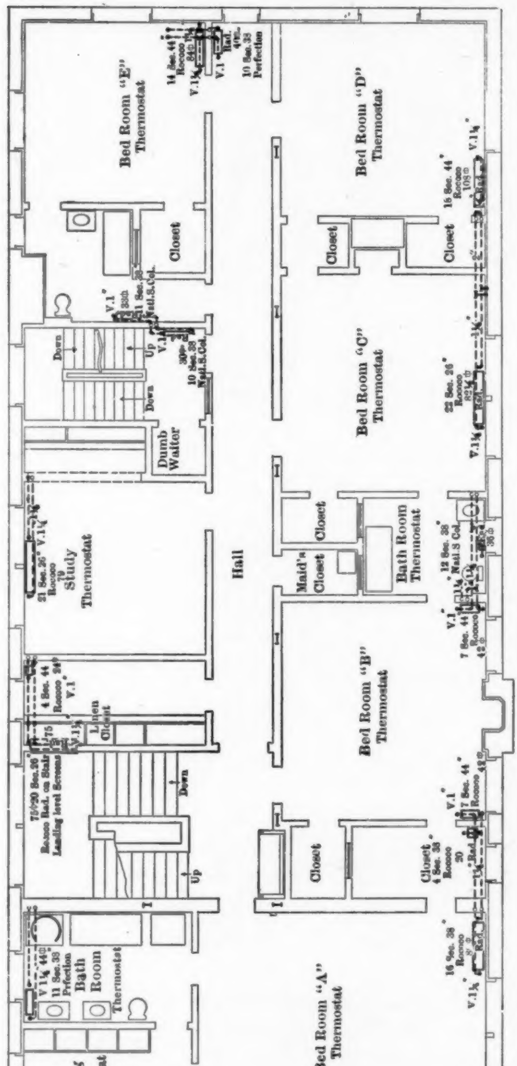
FEBRUARY 20, 1905.

| Temperatures taken at | 7 A.M. | 9 A.M. | 11 A.M. | 1 P.M. | 3 P.M. | 9 P.M. |
|---|---|---|---|---|---|---|
| | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* |
| Outside | 32 | 32 | 38 | 38 | 36 | 32 |
| Water supply | 142 | 140 | 140 | 138 | 140 | 140 |
| Water return | 124 | 120 | 118 | 115 | 118 | 120 |
| Cold-air room | 58 | 56 | 50 | 48 | 48 | 46 |
| Servants' dining room | 70 | 70 | 70 | 70 | 70 | 70 |
| Parlor | 70 | 70 | 72 | 72 | 70 | 70 |
| Billiard room * | 66 | 66 | 66 | 66 | 64 | 64 |
| Conservatory | 60 | 64 | 65 | 65 | 65 | 65 |
| Reception hall | 72 | 72 | 72 | 72 | 70 | 70 |
| Amt. fuel consumed during day | 520 pounds anthracite coal. | | | | | |

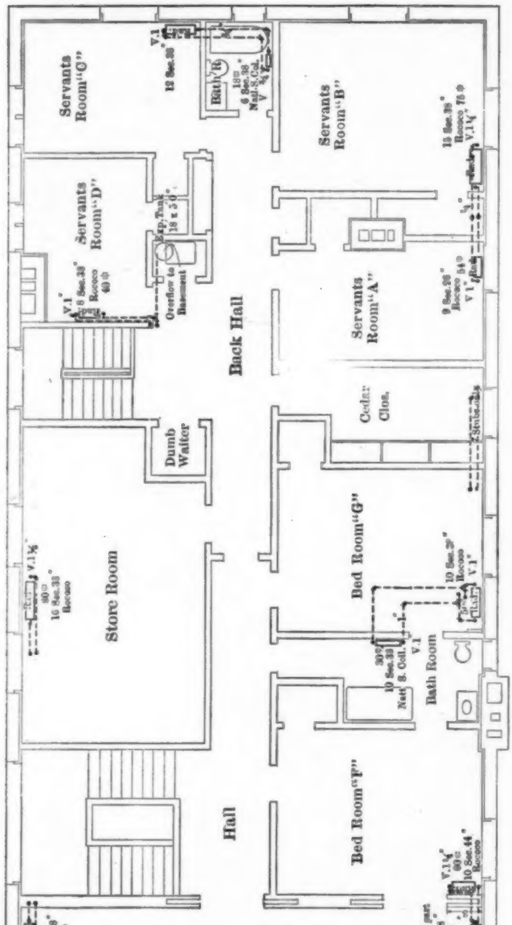
* One register closed.




FIRST FLOOR PLAN.




SECOND FLOOR PLAN.




THIRD FLOOR PLAN.

THE AVERAGE DAILY TEMPERATURES BETWEEN 7 A.M. AND 9 P.M.—FOR SEVEN DAYS.

| | 14th. | 15th. | 16th. | 17th. | 18th. | 19th. | 20th. | For Seven Days. |
|---|---|---|---|---|---|---|---|---|
| | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* | *Degrees.* |
| Outside | 8 | 2.3 | 18.16 | 23 | 22.66 | 29.83 | 34.66 | 18.80 |
| Water supply | 169.5 | 172.33 | 170.16 | 170 | 159.33 | 158.01 | 140 | 162.76 |
| Water return | 160.6 | 147.66 | 150.33 | 154.83 | 154 | 138.83 | 119.01 | 146.46 |
| Cold-air room | 58.33 | 42.66 | 51 | 59.66 | 58 | 54.33 | 56 | 54.28 |
| Servants' dining-room | 71 | 70 | 70 | 70.33 | 70 | 69.66 | 70 | 71.57 |
| Parlor | 65.33 | 76.33 | 74.5 | 74.66 | 72.66 | 70 | 70.66 | 72.02 |
| Billiard room | 54 | 56.16 | 63 | 67.66 | 67.66 | 65 | 65.33 | 62.68 |
| Conservatory | 58 | 65.33 | 65 | 68.33 | 61.5 | 66.16 | 64 | 61.18 |
| Reception room | 70.33 | 73.83 | 74.33 | 74 | 73.66 | 71.33 | 71.33 | 72.68 |

Average amount of coal consumed each day, 718 lbs.

Two boilers were in operation on the 15th, and only one boiler on the 19th and 20th.

At the time the test was made, the automatic regulation was not in perfect order until 11 A.M. on the 20th, and since that time the plant has been working very successfully, and the consumption of fuel has been reduced.

In plants of this description, it would be a good plan for architects and engineers to include in specifications "a week's operation by competent persons," as the ordinary house man is not capable of operating a plant of this description in a satisfactory manner to both owner and contractor.

## DISCUSSION.

The Secretary: I have a request from Professor Kent, who asks a question in connection with the Capron paper: "Has he any means of judging how much of the heat generated was used to heat the air discharged from the building for ventilation and how much to supply the radiation for conduction through the walls, windows, etc.?"

Mr. Capron: I have no means of answering that question. I could not make that test from what data I have.

Mr. Brennan: I would like to ask Mr. Capron how he arrived at the amount of radiation, what formula he used?

Mr. Capron: The formula I used was a proportion of one square foot of radiation to two square feet of glass; one square foot of radiation to ten square feet of wall surface; one square foot of radiation to 60 cubic feet of contents, with an addition

of 50 per cent. for the indirect, and about 10 per cent. for the corner rooms in addition.

Mr. Brennan: I would also like to ask how the capacity of the boilers in relation to the amount of radiation in the building was arrived at.

Mr. Capron: I think the boilers are rated for about 30 per cent. more than the total amount of radiation of the buildings, plus 25 per cent. for mains and risers, and added about 20 per cent. to that. The boilers are quite ample for the amount of radiation.

Mr. Widdicombe: Have you any idea, Mr. Capron, about the relative cost of operation of this plant compared with a steam plant applied to the same use indirect?

Mr. Capron: No, I have not made a test of a steam plant similarly constructed, with the same sized building. I would not pass any judgment on that.

The Secretary: I would like to ask Mr. Capron how or why this particular type of boiler was selected for the building, for the reason that in the East we do considerable indirect hot-water heating, and in the majority of cases we have been using, feeling that we were treating the case better, a cast-iron boiler; and I would like to find out why he selected this particular type of boiler for this building.

Mr. Capron: That is a good deal a matter of opinion, as regards the cast-iron type of boilers. We are using many of them in the West. After talking it over with the architects and owners, I think they decided that they preferred that boiler to the cast iron. But I don't know as they had any very good reason for it. There were objections to both of them. We have a number in operation for a number of years, and they have always given very good satisfaction. When properly installed, I don't think there is any objection to them.

The Secretary: I only brought it up at this time in that connection to ascertain whether it was an expression of his opinion, or a request of the owner or the architect, or something of that sort. Our experience in the East is that our wrought-iron tubular boilers go to pieces in the summer months when they are not in use.

Mr. Munroe (of Baltimore): In selecting this particular boiler, I would like to ask Mr. Capron if, as I understand, it is a loco-

motive type of boiler, brick set, whether it had cast-iron rings at the bottom around the fire door, that is, or steel welded rings?

Mr. Capron: This boiler had a steel welded ring.

Mr. Brennan: I would like to ask Mr. Capron what was the construction of the boiler with regard to the flues, the manner of bricking, the manner of the taking the smoke up from the boiler?

Mr. Capron: The boiler had all the flues in it we could possibly put in. It had about twelve or fourteen more than the ordinary boiler is constructed with to-day. It was simply crowded with flues; the brick setting was arranged so that the smoke passed around the boilers three times and was taken out at the rear; went down under, back in front, over the top and out at the rear.

Mr. Brennan: Was the smoke area greater with the hot-water boiler than if you used it as a steam boiler?

Mr. Capron: The same proportion.

Mr. Brennan: It was greater than the combined area of all the tubes.

Mr. Capron: It made it about 25 per cent. greater than the combined area of the tubes. The boiler contained more tubes than the ordinary steam boiler.

Mr. Hoffman: I would like to ask what ratio the gentleman used between the area of the cross section, what we call our intake, and the cross-section area of the heated waterstack?

Mr. Capron: To each individual stack?

Mr. Hoffman: To the sum total.

Mr. Capron: About one square inch area to a square foot of radiation.

Mr. Larson: I would like to ask the author of that paper how his flues were placed in this case, whether staggered or in horizontally or in a vertical row; and as to how they were spaced, whether far apart or not; and also if in his judgment there is not danger in getting too many flues in of destroying circulation?

Mr. Capron: The flues were in horizontal and vertical rows. The spacings, I should say, were about two inches between the flues. From the operation of the plant, and the circulation obtained around the system, I should not think the circulation was retarded at all; it had very good circulation throughout the entire operation.

The Secretary: As I understand it, it merely increased the

number of tubes by filling what would be the steam space with additional tubes, so as to make it a hot-water boiler.

Mr. D. F. Morgan: I would like to ask Mr. Capron whether in his opinion a cast-iron boiler, treated in the same manner as to bricking as a fire-box boiler, would not give better results?

Mr. Capron: Well, better results in regard to economy of operation, or as regards circulation?

Mr. Morgan: Well, both; I had in mind the economical operation.

Mr. Capron: I don't think there would be any great difference in economy, from what experience I have had. The brick setting, of course, would help it to some extent, no question about that.

Mr. Morgan: The boiler was bricked so that the gases returned around the bottom of the boiler, and were passed off at the top at the back of the boiler. Is that correct?

Mr. Capron: Yes, sir.

Mr. Morgan: If that was reversed, wouldn't there have been more economy? The fact of the gases leaving the boiler at the point where the water was the coldest would have abstracted more heat from the gases, would it not?

Mr. Mackay (Chicago): That would depend upon the gases as they left the fire chamber.

Mr. Morgan: I might say that this manner of bricking fire-box boilers has never appealed to me. As a matter of fact, a fire-box boiler has never appealed to me anyway. In a fire-box boiler 35 per cent. of the heating surface does 65 per cent. of the work. I think that with a great number of flues and a large amount of grate surface, the best results are obtained from the bricking in of the boiler. Now, I have bricked in a cast-iron boiler, and I bricked it the reverse way of Mr. Capron. I passed the gas off at the top, going forward and down and going to the chimney at the bottom of the boiler, and I found the results for economy were very great indeed; and it is a practice we have adopted in our construction of bricking in cast-iron boilers. I think from the fact we have larger flue space for the gas to travel through and become ignited, that we can get much better results from them than we can from a fire-box boiler under the same conditions.

The Secretary: We are going into the question of boiler con-

struction rather than heating of the building. But I just want to agree with Mr. Morgan in one thing that he says, that he could get better results from a cast-iron boiler. And then I want to say that in my opinion a properly constructed cast-iron sectional boiler does not require bricking in in order to make it give better results. It is only when defective in construction that it requires the use of brick work.

Mr. Morgan: I think I have to take issue with Mr. Mackay about one thing. Isn't it a question of the heating on the inside of the boiler, and leaving the outside to do the condensing? The condensation of your heating medium is supposed to take place in the radiator. I think the covering of the boiler with asbestos is merely a make-shift. The gas may just as well travel around the outside of the boiler and make a heating surface of the condensation surface as not. I don't want to state what the results were in one instance that I know of, because it would be very hard to believe, and then Mr. Mackay would go back and say it was the fault of the boiler, which I do not believe.

Mr. Thompson: I would like to inquire why, in assuming the ratio of radiating surface in the building to be heated, so much weight is given to the cubic contents in proportion of the wall surface and glass surface? I have not had time to figure this out, but in looking at it I should judge that the number of square feet given on account of the cubic contents are very much greater than the number of square feet for the door surface and wall space combined. Why was that plan adopted?

Mr. Capron: I have used that formula for the past ten or twelve years, and have been very successful with it. My work has given good satisfaction and come out very nicely. We have not had to go back and add a lot of radiation from time to time, and it always seems satisfactory. You get the proportion of the house by the rooms; it is simply a matter of proportion. It has always proven satisfactory to me.

Mr. Widdicombe: I would like to ask Mr. Capron if it is not a fact that Mr. Mackay's remark about the steel boiler falling down in the summer time does not equally apply to a cast-iron boiler cracking in the winter time?

Mr. Capron: I think that a cast-iron boiler will crack if it freezes in the winter time. What the results would be with the fire-box boiler under the same conditions it is hard to say. Of

course it would not damage the boiler to the same extent. I think there are points in favor of both boilers. The conditions of the building, the opinions of the architect and owner often influence the engineer in deciding what he is to use. I have had trouble with both steel and cast-iron boilers.

Mr. Larson: There is another objection to the fire-box boiler that I have not heard mentioned; that is, that it is impossible in a fire-box boiler to get up the heat in the furnace that is required for good combustion. For perfect combustion, it is necessary to have the fire-box of your furnace as hot as possible. You can't get your furnace in the fire-box boiler as hot as you can in the brick furnace.

Mr. Munroe: I would like to ask Mr. Capron if he had any particular reason for placing the radiation around on the second and third floor other than under the windows? It seems to me nowadays there is a wide difference of opinion among engineers as to the amount of surface necessary to heat rooms of varying exposures, also regarding the placing of radiators under windows, or otherwise than under the windows. I would like to hear some expression of opinion as to whether it is still adhered to as being always the best practice to place radiators under the windows.

Mr. Capron: In this case the radiators were located to suit the owners of the building. I always liked to have the radiators on the outside walls and under the windows if possible. I don't think there is much difference between the outside walls and the window, as regards the heating of the room. Placing the radiator over in the centre of the room, on the inside wall, I used at least 25 per cent. additional radiation—usually add at least that much. But we have to follow the wishes of the owner to a certain extent in the location of radiators at all times.

Mr. Donnelly: I don't understand Mr. Capron when he says he adds 25 per cent. additional radiation for the radiators when used on the inside walls. There is no 25 per cent. more loss from the outside walls, and the radiators ought to come much closer than 25 per cent. of maximum transmission. One other fact which Mr. Munroe spoke about, and I brought up a while ago—that was, if the radiators were located under the windows and the air delivered through them varies, as it does with either steam

or water, running probably from 100 to 150 degrees, if the air is maintained passing up in front of the window, keeping that surface practically filled with air at 100 to 150 degrees, the heat loss from that glass isn't 70 degrees, the difference between the inside and outside, but from 100 to 120 degrees difference. It is not absolutely correct if you figure 70 degrees difference; if your radiator is on the inside of the room it heats the wall surface; if it is an outside exposure, the outside surface and the glass surface would not be over 70 degrees. With very high ceilings, the real exposure and the real loss of heat is not 70 degrees at the top of the window; it is nearer 75, and at the floor it is a little less than 70. In very high ceilings it may be more. It seems to me it is always the same way, that if you put your radiator under the window you have to have more radiation than if you put it along the inside wall.

Mr. Thompson: My question about the proportion of radiating surface, etc., was based on the fact that I spent last winter in a house heated with hot water, and the house was a little peculiarly built. There was one room in it which had a good deal of cubic contents and very little wall surface, very little glass surface; another room which had very much less cubic contents had more than double the wall surface and glass surface. The room which had the small amount of surface and large cubic contents was easy to heat; the other room with the larger amount of wall and glass surface, but smaller amount of cubic contents, it was difficult to get up to sixty. It impressed me right there that the general plan might be all right for a different room and a different house; but that a rule ought to be so made that you could heat every room in any house if we are going on the correct principle and sound practice. The rule where cubic contents are considered may work with some rooms, but rooms vary, and you often get a peculiarly situated room. We ought to have a rule which would cover peculiar rooms as well as ordinary rooms.

The Chairman: Any further discussion?

Mr. Jas. Mackay: The remarks that have been made with reference to the boiler and figures as to radiation, etc., all apply and are pertinent. I do not think it is possible to formulate a rule for figuring radiation that will apply hard and fast to every condition. It is very easy to assume that a given amount of radia-

tion will offset a given exposure. But the amount of air that is leaking in through a given window at any time is simply a matter of some individual's judgment. I can estimate according to my judgment that it is 5 cubic feet of air an hour; another man might estimate 10, and another might estimate 15; that is where the judgment of the engineer enters into the question. Mr. Capron's figures have been followed in his practice, checked off against different results, and have proven satisfactory. Now, no doubt if he had other problems to handle he would change his formula to suit the conditions as he finds them. The boiler with a fire-box construction is one that is very largely used in this section of the country for both steam and water. It is true they deteriorate in the summer season, when they are not in use; but we have a sandy soil here, so that perhaps they do a little better service from the standpoint of durability than they do in some other sections of the country. I have seen them go to pieces in four years. Now, take a cast-iron sectional boiler, with the same amount of grate area as the fire-box boiler, and you will have a larger amount of heating surface, consequently greater economy. The trouble is, that it has become the practice of heating contractors to use the boiler given to him by the boiler manufacturer; but the sectional boiler maker has begun to look closer into the question of ratings. Take the two boilers, the fire-box and sectional construction, with the same grate area, the sectional boiler will be far more economical, especially if erected as Mr. Morgan has said.

The Chairman: Any further discussion on this paper? Mr. Capron, under the rules you have a right to close.

Mr. Capron: I just want to say that the general style of the heating plant which this paper refers to is somewhat different, I think, from the ordinary house-heating plant that is put in. I don't remember now of more than one residence in Chicago having hot-water indirect heat with a tempering chamber, having an automatic pass-by damper.

It is somewhat peculiar in its construction, and that is one reason why I sent it in to the Association. There was one point in regard to the test, or the turning over of the plant to the owner. After having a man there about a week, we taught him the operation of the plant. I think that with plants of this de-

scription, and with a great many other plants, that before turning them over to the owner the man in charge—who as a rule is not a licensed engineer, or has not had much experience—should have a week's tuition with a competent man. I think the general results would be far better from the contractor's standpoint and the engineer's and owner's as well.

# CXLV.

## FLOW OF AIR IN METAL PIPES.

BY J. H. KINEALY.

The expression for the friction of the flow of air in metal pipes of a circular or square cross-section may for all practical purposes be taken as

$$(1) \qquad F = \left(\frac{v}{5,200}\right)^2 \frac{0.3\ l}{d}.*$$

* The derivation of equation (1) is as follows:

The head, $h$, required to overcome the friction of the flow of any fluid in a pipe of circular or cross-section is

$$(A) \qquad h = \frac{v^2}{2g} \times \frac{4fl}{D},$$

in which $v$ is the velocity in feet per second of the fluid in the pipe; $f$ is the coefficient of friction of the fluid; $l$ is length of the pipe in feet; $D$ is the diameter or side of the pipe, *in feet;* and $g$ is 32.2, about.

$f$ may be taken as about 0.006, so that $4f$ is equal to about 0.025. And if we let $d$ be the diameter, or side of the pipe *in inches*, we have $D = \frac{d}{12}$, and, therefore,

$$\frac{4f}{D} = \frac{0.025 \times 12}{d} = \frac{0.3}{d}, \text{ about.}$$

Putting this value of $\frac{4f}{D}$ in ($A$), we have

$$(B) \qquad h = \frac{v}{2g} \times \frac{0.3\ l}{d}.$$

In ($A$) and ($B$) $h$ is the head expressed in feet of the fluid flowing through the pipe. If we express it as a pressure, $F$, per square inch, we get

$$(C) \qquad F = \frac{v^2}{k^2} \times \frac{0.3\ l}{d}.$$

If now we consider air at a temperature of about 56° F., and express the pressure in *ounces per square inch* and the velocity in feet *per minute*, instead of feet per second, $k$ is the velocity in feet per minute with which air at a temperature of about 56° F. will flow under a difference of pressure of one ounce per square inch. That is, $k$ is 5,200.

Now, the force or pressure required to overcome the friction is exactly equal to the friction itself, and hence we may say that the friction of air flowing in a round or square metal pipe is, as given in equation (1),

$$F = \left(\frac{v}{5,200}\right)^2 \frac{0.3\ l}{d}.$$

In this formula, $F$ is the loss of pressure due to friction, in ounces per square inch; $v$, the velocity of the air in feet per minute; $l$, the length of the pipe in feet; and $d$, the diameter in inches of the pipe if round or the side if square.

If we solve (1) for $v$ we get

$$v = 9{,}500 \sqrt{\frac{d\,F}{l}}. \tag{2}$$

If the pipe is round its area of cross-section in square feet is

$$\frac{0.7854\,d^2}{144} = \frac{d^2}{183};$$

and if the pipe is square its area of cross-section in square feet is

$$\frac{d^2}{144}.$$

The product of area of cross-section in square feet, multiplied by the velocity of flow through the pipe in feet per minute, is equal to the cubic feet, $C$, of air flowing through the pipe per minute.

That is, for a round pipe,

$$C = \frac{9{,}500\,d^2}{183}\sqrt{\frac{d\,F}{l}} = 5.2\sqrt{\frac{d^5\,F}{l}}, \quad \text{about}; \tag{3}$$

and for a square pipe

$$C = \frac{9{,}500\,d^2}{144}\sqrt{\frac{d\,F}{l}} = 6.6\sqrt{\frac{d^5\,F}{l}}, \quad \text{about}. \tag{4}$$

These equations apply only to smooth pipes, and since it is impossible to make in practice pipe which shall be smooth everywhere inside, it is better to say

$$C = \begin{cases} 4.4\sqrt{\dfrac{d^5\,F}{l}}, & \text{for a round pipe.} \\[2ex] 5.5\sqrt{\dfrac{d^5\,F}{l}}, & \text{for a square pipe.} \end{cases} \tag{5}$$

An inspection of (5) shows that for all practical purposes we may say that the amount of air which will flow through a round pipe of a given diameter and length, for a given value of $F$, is about 0.8 as much as will flow through a square pipe under the same conditions.

A bend in the pipe tends to increase the amount of friction, and has the same effect as increasing the length of the pipe by an amount which depends upon the ratio of the radius of the middle of the bend to the diameter of the pipe, and upon the diameter of the pipe itself. If we call $e$ this increase in length we may say

$$e = k\,d \tag{6}$$

For a 90-degree bend where the radius of the middle of the bend is $\frac{d}{2}$, $k$ is about 5; and for a 90-degree bend where the radius of the middle of the bend is $d$, $k$ is about 4.

Table I. gives the values of $k$ for 90-degree bends and various values of the ratio obtained by dividing the radius, $r$, of the middle of the bend by the diameter, $d$, of the pipe if round, or the side if square.

TABLE I.

Values of $k$ for various values of $\frac{r}{d}$.

| $\frac{r}{d}$ | $k$ |
|---|---|
| $\frac{1}{2}$ | 5 |
| 1 | 4 |
| $1\frac{1}{2}$ | 3 |
| 2 | 2 |

If we find the equivalent increase of length of a pipe due to each bend, and add this to the length in feet of the pipe, we have what may be termed the *equivalent length* of the pipe, which is always greater than the actual length as measured. Thus, let us suppose we have a square 12-inch pipe, 100 feet long, which has one square bend and one bend for which the radius of the middle is 18 inches or 1.5 times the size of the pipe, and we wish to know the equivalent length of the pipe.

From Table I. we see that $k$ for the square bend, $\frac{r}{d}$ equal $\frac{1}{2}$, is 5; and for the other bend, where $\frac{r}{d}$ is 1.5, $k$ is 3.

Hence for the square bend the increase in length is

$$5\ d = 60 \text{ feet};$$

and for the other bend the increase is

$$3\ d = 36 \text{ feet}.$$

Therefore, the total equivalent length of the pipe is

$$100 + 60 + 36 = 196 \text{ feet}.$$

That is to say, the loss of pressure from friction of this 12-inch pipe, 100 feet long and having the two bends, is the same as it would be in a straight 12-inch pipe 196 feet long.

It is evident that we may assume various values of $d$, $F$, and $l$ in (5) and calculate the amount of air which would flow through the pipe under the assumed conditions.

Table II. gives the values of $C$ for various values of $d$ and $F$ for square pipes 100 feet long, as calculated by (5).

TABLE II.

CUBIC FEET OF AIR THAT WILL FLOW PER MINUTE THROUGH SQUARE PIPES OF VARIOUS SIZES, 100 FEET LONG, FOR VARIOUS VALUES OF F.

| SIZE OF PIPE IN INCHES. | $F$, OR LOSS BY FRICTION IN OUNCES PER SQUARE INCH. | | | | | | AREA OF CROSS-SECTION OF PIPE IN SQUARE INCHES. |
|---|---|---|---|---|---|---|---|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | |
| 6 | 150 | 220 | 270 | 310 | 340 | 370 | 36 |
| 8 | 320 | 440 | 540 | 630 | 700 | 770 | 64 |
| 10 | 560 | 780 | 950 | 1,100 | 1,200 | 1,350 | 100 |
| 12 | 870 | 1,200 | 1.500 | 1,700 | 1,950 | 2,100 | 144 |
| 14 | 1,300 | 1,800 | 2,200 | 2,600 | 2,800 | 3,100 | 196 |
| 16 | 1,800 | 2,500 | 3,100 | 3,500 | 4,000 | 4,300 | 256 |
| 18 | 2,400 | 3,400 | 4,100 | 4,800 | 5,300 | 5,800 | 324 |
| 20 | 3,100 | 4,400 | 5,400 | 6,300 | 7,000 | 7,700 | 400 |
| 22 | 4,000 | 5,600 | 6,900 | 7,900 | 11,000 | 12,000 | 484 |
| 24 | 4,900 | 6,900 | 10,400 | 12,000 | 13,000 | 15,000 | 586 |
| 26 | 6,000 | 8,500 | 12,500 | 14,500 | 16,000 | 18,000 | 676 |
| 30 | 7,200 | 10,200 | 15,000 | 17.000 | 19,000 | 21,000 | 900 |
| 34 | 11,800 | 12,200 | 20,000 | 24,000 | 26,000 | 29,000 | 1,156 |
| 38 | 15,500 | 16,600 | 27,000 | 31,000 | 35,000 | 38,000 | 1,444 |
| 42 | 20,000 | 28,000 | 34,000 | 40,000 | 44,000 | 48,000 | 1,764 |
| 46 | 25,000 | 35,000 | 43,000 | 50,000 | 56,000 | 61,000 | 2,116 |
| 50 | 31,000 | 43,000 | 55,000 | 62,000 | 69,000 | 75,000 | 2,500 |

Table II. is made for square pipes, but it can be used for rectangular pipes that are not square and also for round pipes.

The table may be used for any rectangular pipe whose longest side is not more than twice its shortest. Thus the friction in a rectangular pipe 7 by 14 inches is only about 5 per cent. more than that in a square pipe 10 by 10 inches of the same length. As long as the short side of the cross-section of the pipe is not less than one-half the length of the long side, the friction in the rectangular pipe will not be more than 5 per cent. greater than the friction in a square pipe of the same area of cross-section and the same length; and a difference of 5 per cent. is too small to be considered in such work as laying out a system of pipes for a heating or ventilating system.

Table II. may be used for round pipes if we remember that the number of cubic feet of air carried by a round pipe of a given diameter and length is 0.8 of the number of cubic feet of air carried by a square pipe of the same length whose side is equal to the diameter of the round pipe. Thus the table shows that the friction of 1,100 cubic feet of air passing per minute through a square pipe 10 by 10 inches and 100 feet long is 0.4 of an ounce. A round pipe 10 inches in diameter and 100 feet long would have the same friction if 880, equal $0.8 \times 1,100$, cubic feet of air passed through it per minute.

Table II. may be used to determine the size of pipe required to carry a given amount of air per minute with a given loss by friction. This may best be made clear by examples.

Example 1. Determine the size of a rectangular pipe required to deliver 3,000 cubic feet of air per minute a distance of 100 feet with a loss by friction of 0.2 of an ounce.

Looking under the column headed 0.2, we find opposite 16 in the first column, 2,500; and opposite 18 in the first column we find 3,400. That is, a 16-inch square pipe will deliver 2,500 cubic feet of air per minute a distance of 100 feet with a loss by friction of 0.2 of an ounce; and an 18-inch square pipe will deliver 3,400 cubic feet of air per minute the same distance with the same loss. Since 3,000 is about midway between 2,500 and 3,400 it is evident that we need a 17-inch square pipe, since it is midway, almost at least, between a 16-inch and an 18-inch pipe.

If we do not want to use a square pipe we proceed as follows: The area of a 16-inch square pipe which will deliver 2,500 cubic feet per minute is, from the table, 256 square inches, and the

area of an 18-inch pipe which will deliver 3,400 cubic feet per minute, is 324 square inches. The mean of these is 290, equal $\frac{256 + 324}{2}$, square inches. That is, the pipe must have an area of 290 square inches to deliver 3,000 cubic feet of air 100 feet with a loss by friction of 0.2 of an ounce. We may use a pipe 12 by 24; or 15 by 20; or 16 by 18 inches.

Example 2. Determine the diameter of a round pipe that will deliver 10,000 cubic feet of air per minute a distance of 100 feet with a loss by friction of 0.5 of an ounce.

Since, as has been pointed out, a round pipe will deliver only 0.8 as much air as a square pipe of the same size with the same loss by friction, if we *divide* 10,000 by 0.8 we get the amount of air which a square pipe of the same size as the required round pipe will deliver. And 10,000 divided by 0.8 is 12,500.

Looking under the column headed 0.5, we find that a 24-inch square pipe will deliver 13,000 cubic feet of air per minute with a loss by friction of 0.5 of an ounce. Hence a 24-inch round pipe is what we shall use.

Example 3. Determine the size of a square pipe required to deliver 1,500 cubic feet of air per minute a distance of 300 feet with a loss by friction of only 0.1 of an ounce.

Since the friction increases as the square root of the length of the pipe, delivering 1,500 cubic feet of air 300 feet is equivalent to delivering at a distance of 100 feet an amount of air equal to 1,500 multiplied by the square root of the quotient obtained by dividing 300 by 100. The quotient obtained by dividing 300 by 100 is 3; and the square root of 3 is 1.7.

Hence the pipe which will deliver 1,500 cubic feet of air a distance of 300 feet will deliver 2,600, equal 1.7 multiplied by 1,500, cubic feet of air 100 feet with the same loss by friction.

Therefore, we proceed as before, and find the square pipe which will deliver 2,600 cubic feet of air per minute at a distance of 100 feet with a loss of 0.1 of an ounce. This we find must be a 19-inch square pipe, although a pipe 18 by 19 inches will be large enough.

Example 4. Determine the size of pipe 150 feet long with one square 90-degree bend and two curved 90-degree bends, required to deliver 2,000 cubic feet of air per minute with a loss by friction of 0.3 of an ounce.

In working such an example as this it is usual to assume first the probable increase in the amount of air to compensate for the length and bends, and by practice one soon learns to assume about the proper increase. Here, however, we shall assume no increase at all and proceed as follows:

Delivering 2,000 cubic feet of air 150 feet is equivalent to delivering 2,500, equal 2,000 multiplied by the square root of the quotient obtained by dividing 150 by 100, cubic feet of air 100 feet. And the table shows that for a loss 0.3 of an ounce a 15-inch pipe will be required. We may assume that for the square bend $k$, given in Table I., is 5; and for each of the round bends $k$ is 3. Hence the equivalent length due to the bends is

$$5 \times 15 + 2 \times 3 \times 15 = 75 + 90 = 165 \text{ feet.}$$

The equivalent length of the pipe, therefore, is

$$150 + 165 = 315 \text{ feet.}$$

That is, because of the bends we must deliver the air not 150 feet, but 315 feet. And delivering 2,000 cubic feet of air 315 feet is equivalent to delivering 3,600, equal $2{,}000 \times \sqrt{\frac{315}{100}}$ cubic feet of air 100 feet.

From Table II. we see that a 17-inch pipe will be required to deliver 3,600 cubic feet of air a distance of 100 feet with a loss by friction of 0.3 of an ounce.

But the equivalent length due to the bends in the 17-inch is

$$5 \times 17 + 2 \times 3 \times 17 = 85 + 102 = 187$$

instead of 165 as assumed.

And the equivalent length of the pipe is

$$150 + 187 = 337 \text{ feet.}$$

And delivering 2,000 cubic feet of air 337 feet is the same as delivering 3,700, equal $2{,}000 \sqrt{\frac{337}{100}}$ cubic feet a distance of 100 feet.

Table II. shows that a 17-inch pipe is not quite large enough, but nearly so, to deliver 3,700 cubic feet of air per minute a

distance of 100 feet with a loss by friction of 0.3 of an ounce. A pipe 17 by 18 would be amply large.

Table II. shows very clearly how and why it is that the friction of the flow of air in a round pipe is different from the friction of the flow of air in a square pipe. Thus, suppose we wish to determine the size of a square pipe and also the size of a round pipe capable of delivering 2,000 cubic feet of air a distance of 100 feet with a loss by friction of 0.2 of an ounce.

Turning to Table II., we see that a 14-inch square pipe will deliver 1,800 cubic feet of air a distance of 100 feet with a loss by friction of 0.2 of an ounce, while a 16-inch square pipe will deliver 2,500 cubic feet of air the same distance with the same loss. That is, the 14-inch pipe is slightly too small and the 16-inch pipe is too large. We should use, therefore, a 15-inch square pipe.

To find the round pipe required, we divide 200 by 0.8 and get 2,500. Then we look in Table II. and find the size of pipe required, and this will be the size of round pipe required to deliver 2,000 cubic feet of air a distance of 100 feet with a loss of 0.2 of an ounce by friction. From the table we see that an 18-inch pipe will be required. That is, an 18-inch square pipe will deliver 2,500 cubic feet of air a distance of 100 feet with a loss by friction of 0.2 of an ounce, while an 18-inch round pipe will deliver 2,000 cubic feet of air a distance of 100 feet with a loss by friction of 0.2 of an ounce.

In other words, the round pipe must be 18 inches in diameter, while the square pipe need be but 15 inches on the side. The round pipe must be 20 per cent. larger than the square pipe in order to deliver the same quantity of air with the same loss by friction. A round pipe of the same size as a square pipe of a given length will have just exactly the same loss by friction as the square pipe and will deliver only about 0.8 as much air as the square pipe. Further, the round pipe will take up just as much room or space as the square pipe.

A square pipe is better than a round pipe, because it will deliver more air for the same loss by friction and will take up no more space. True the square pipe will contain more metal than the round pipe, whose diameter is equal to the side of the square pipe, and the square pipe will cost more to make.

The formulas and table given here may be used to lay out

all kinds of systems of piping for air, and I hope that the members of the society will find them as useful and convenient in their work as I have.

DISCUSSION.

Mr. Donnelly: I would like to ask Professor Kinealy a question. At the top of page 6 he says, "Since the friction increases as the square root of the length of the pipe, delivering 1,500 cubic feet of air 300 feet is equivalent to delivering at a distance of 100 feet an amount of air equal to 1,500 multiplied by the square root of the quotient obtained by dividing 300 by 100." I could never make the loss due to friction, as given in some of the author's works, agree with loss of friction and loss of pressure of steam. For instance, Babcock's formulæ for steam gives the loss of pressure due to friction as directly proportional to the length. Twice the length, twice the loss in pressure due to friction; and loss of friction due to velocity, as the square of the velocity. Twice the velocity, four times the loss of pressure due to friction. I would like Professor Kinealy to give me some explanation of why this is, "as the square root of the length of the pipe." I don't quite understand that. I don't understand whether it is the Babcock formula, expressed in a different way, or a different handling of the same proposition, or what.

Mr. Kinealy: I think it is probably a difference in the way in which the formulas are read or used. The equation only shows that the friction, or the loss by friction, for the same velocity and the same diameter of pipe, increases directly as the length does. Now, however, when you have a given pipe, a pipe of a given size, and you have a given head or loss, with which you start, you make corrections for variations, as you have varying velocities. You will find by solving the equation, as is done in equation 2, that the velocity is inversely as the square root of the length. In this work, using Table 2, we start with a loss for which we design our pipe. For instance, 0.1 of an ounce or 0.2 of an ounce. That loss must not be exceeded, and hence, from equation 2, we see that as we increase the length or decrease it, the velocity, which is the same as the amount of air, changes inversely as the square root of the length, the difference being that we are starting with different given quantities. We are working with Table

2, and in that we have given the loss of friction and the diameter of the pipe. That is all there is to it.

The Chairman: Any further discussion?

Mr. Stangland: I would like to ask the Professor if this formula holds good on either vacuum or exhaust steam drawings, or the discharge of air through pipes?

Mr. Kinealy: It does not make any difference.

Mr. Stangland: I am inclined to think it does. I would like to hear from some of the members on the question of exhausting air through pipes, or the flow; I am inclined to think there is a difference in the formula.

Mr. Harvey: Some of your furnace men ought to be able to give some light on that point. If there are no further questions to be asked on Professor Kinealy's paper, we will close the discussion.

Mr. Kinealy: I used Table 2 in designing in this way: I determined the loss due to friction of the air passing through my tempering coils, then through the heating coils, and through the fan; then I subtract that total loss from the pressure corresponding to the speed at which I wish to run my fan, and the remainder is the pressure that will be used in overcoming friction. Then I proportioned my pipes accordingly.

In other words, suppose I am laying out a large hot blast job and I wish to run the fan so as to give a pressure of 0.6 of an ounce. I may put in a deep heater, and an air washer, or I may have two or three other things that will increase the resistance to the air, as it passes from the outside through the fan and tempering coil to the heating coil. I find these resistances and add them together. Let me assume that the sum total is, say, 0.35 of an ounce. Subtracting that from 0.6 of an ounce, I have 0.25 left. Now I know that there are going to be various little resistances which I cannot estimate, therefore I will lay out the pipes so that the resistance due to the friction in the pipes and in the flues up to the registers will be 0.2 of an ounce. Then I use this table. I have no doubt but what the friction will vary with different conditions. I know that the smoothness of the pipes and the way in which the pipes are put together affect it very materially, I know that the condition of the flues affects the friction materially, but the mere fact that I do not know how to account exactly for all those things does not keep me

from trying to account for the friction as far as I can. When I lay out the pipes from this table, assuming that the friction will be 0.2 of an ounce, I am perfectly satisfied if it is only 0.15; but I kick if it happens to be 0.25. All the table can do is to aid you. I think you will all agree with me when I say that no formula, no table, no book will make an engineer any more than a box of carpenter's tools will make a carpenter.

CXLVI.

# NOTES ON THE DESIGN OF CENTRAL-STATION HOT-WATER HEATING SYSTEMS.

BY J. D. HOFFMAN.

1. The success attending the operation of central heating plants has been variable; some have worked satisfactorily and others have been failures. The few installations that were first put in, however defective they may have been, fortunately served to stimulate rather than to discourage progress in this line, and as a result in localities where conditions seem to offer special inducements, such plants are regarded with great favor. In the last few years a fruitful field for the application of such systems has been opened up in the Central West, especially such portions of it as have previously been blessed with natural gas. The cheapness of the gas as a fuel and the great convenience attending its use have up to this time served as barriers to other methods of heating. Now that the supply of gas is becoming so limited as to demand some other system, people are choosing between the private heating plant, furnace, steam or hot water and the central or district system. The element of economy enters in the selection of the system, but that of personal convenience in handling and operating is one of the controlling factors.

Owing to the great field which now seems to be opening up along the line of central-station heating, the time seems ripe for a general interchange of opinion concerning the design of such systems. The importance of the subject cannot be questioned, and since the society has not touched upon it to any great extent, it is hoped that this paper may be taken as an initiative, and that it may provoke friendly discussion among the members, so that in meetings following this, other papers upon other phases of the subject may be presented.

Many articles are to be found in the technical press on central-station or district heating, but these give mainly descrip-

tions of the equipment and method of operation without entering into the reasons underlying the design of the various parts. The subject of heat transmission, when applied to actual cases, is one that follows closely to the theoretical development, and it is natural to assume that this branch of it will permit rational deductions. Because of this assumption, therefore, and because there is so little precedent to follow, also because there are others in the society who are so well informed along the lines here discussed, the writer feels some hesitation in submitting this contribution for the close analysis which it is sure to receive.

No great degree of originality need be claimed in the methods employed in the paper; rather, there has been an attempt to follow out logically and in sequence the various points of a typical design along existing and well-known lines, so as to point out how such work may be done.

2. *Conditions to be Fulfilled.*—In the following only two-pipe hot-water heating is considered. A certain portion of an imaginary city, Fig. 1, is assumed as available territory. In this territory is located an electric lighting plant (A) having a maximum output of 250 K. W. or approximately 333 H. P. In connection with this lighting plant is installed, as an integral part, a hot-water heating system using the exhaust steam from the lighting engines in reheaters to heat water which in turn is forced through the street mains to the various houses. The maximum amount of heating surface to be supplied from this power plant is taken at not greater than 100,000 square feet.

3. *Territory to be Occupied and Gallons of Water Needed.*— To obtain an estimate of the number of houses that can be heated and the possible territory covered, it is necessary to know the amount of heat lost per hour from the average residence and then from the average square. Take as a unit of measurement a 12-foot by 15-foot by 10-foot corner room having three 3-foot by 6-foot windows, located on the first floor in any residence and apply the formula given in Carpenter's "Heating and Ventilating of Buildings," page 70. The heat loss from this room is

$$H = \left(G + \frac{W}{4} + \frac{NC}{55}\right)(t - t'), \quad \text{where}$$

$G$ = area of the glass = 54.
$W$ = area of exposed walls = 216.
$C$ = volume of the room = 1,800.
$N$ = changes of air in the room per hour = say 2.
$t$ = temperature of the room air = 70°.
$t'$ = temperature of the outside air = 0°.

Substituting in the above, we find the heat loss from such a room per hour to be 12,145 B. T. U. To determine the amount of water necessary to pass through the radiators to supply this heat loss, assume the water to enter the radiator at 175 degrees and leave the radiator at 155 degrees, giving off approximately 20 B. T. U. per pound in the residence. If this room were supplied by heat from a central station there would be an approximate loss in the street mains of 5 degrees coming and 5 degrees returning, which makes an additional loss of about 10 B. T. U. per pound of water. Considering the radiator itself, it will require $12{,}145 \div 20 = 607$ pounds of water per hour. This is equivalent to 72.7, say, 73 gallons of water per hour. To find the square feet of hot-water heating surface to heat this room we have

$$\text{Radiation} = 12{,}145 \div 1.7\,(T - t),$$

where $T$ is the average temperature of the water within the radiator = 165 degrees; $t$ is the temperature of the room = 70 degrees and 1.7 is the heat transmission through one square foot of cast iron radiation per hour per degree difference in temperature. From this we obtain the requirement of approximately 73 square feet of water heating surface. This makes one gallon of water per hour for each square foot of heating surface in the room.

The assumed room may be taken as an average of most rooms in residence heating, and in moderately cold weather with a house of ordinary construction the above figures would hold good. In case of extreme cold weather or poor house construction, the temperature of the water may be raised. It is not an uncommon thing to have the temperature of the water in the radiators near 200 degrees. This would permit the same volume of water to pass the radiator per hour and

still provide enough additional heat to the room to take care of almost any unusual heat loss.

Each residence square is taken at 3,500 square feet of heating surface, and each business square at 7,000 square feet. Allowing 20 residence squares and 4 business squares as indicated within the limits of the dotted lines, Fig. 1, we have approximately 100,000 gallons of water moved through the system each hour. This will require the pumps at the power plant to deliver 28 gallons per second.

4. *Size of the Mains*.—Having given the requirement of the plant at 28 gallons of water per second, the area of the main at the power plant can be obtained as follows: In a two-pipe (main and return) hot-water system, take the velocity of the water at the power plant at 7 feet per second, and in the outlying mains at 5 feet per second. Allowing 7 feet per second, the area of the pipe is 76.5 square inches, which is equivalent to a pipe of 10 inches diameter. In the same way with an assumed velocity of 5 feet per second, mains at any point toward the end of the run may be obtained.

Referring to Fig. 1, which gives the proposed layout of the pipes for the district, the sizes of the mains would be calculated beginning at the power plant. Knowing the amount of water to be supplied by each one of the mains, any diameter may be obtained by assuming the velocity varying from 5 to 7 feet per second as previously suggested. It is desirable to have service pipes as large as possible consistent with the difficulties which will be met in installing the same. Where two pipes are run in the same conduit a diameter of 10 inches in each main can be laid without great difficulty, but to install pipes of, say, 16 inches or more would require a trench of such a size that it would interfere in the laying of other pipes and wires under a city street, and this is seriously objected to by city ordinances. It is not thought advisable, from the standpoint of economy, to carry more than 100,000 to 150,000 square feet of surface on the average lighting plant, hence a 10-inch to 12-inch main would in few cases be exceeded.

5. *Circulating Pumps*.—To circulate the water through the mains it is necessary to have some pump service attached. The pumps are located on the return line (Fig. 2) near where it enters the building, and, providing an expansion tank is used,

they should take the water directly from it. The pumps may be either of the horizontal reciprocating type or of the centrifugal type. After selecting the type of the pump it should

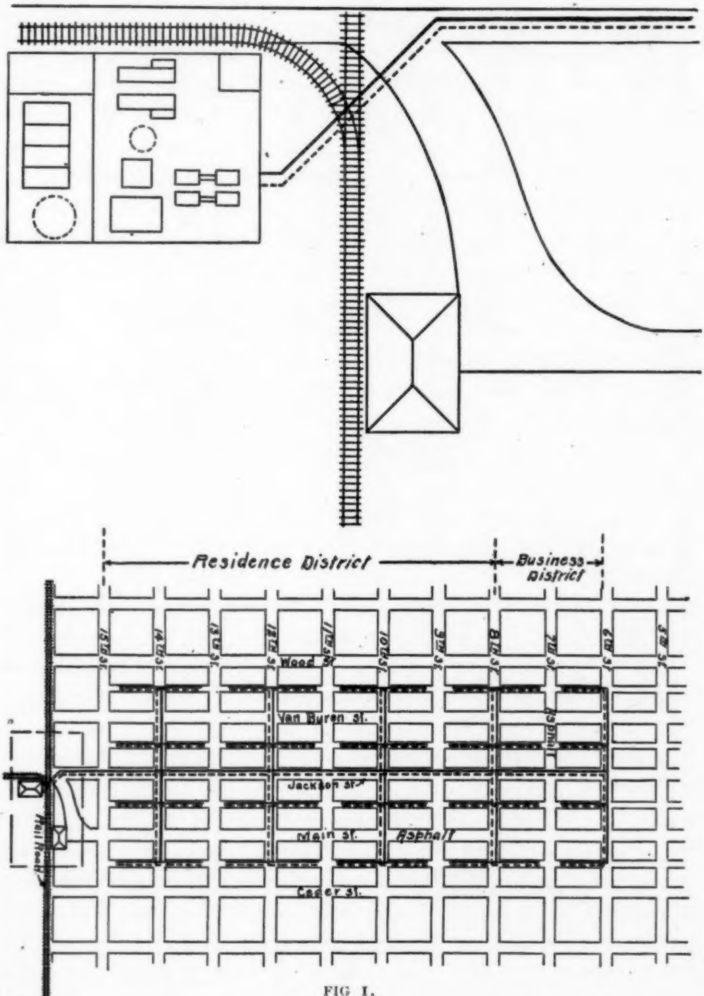



FIG I.

be installed in duplicate in such a way that one or both pumps may be used according to the requirements of the system. The principal reason for installing in duplicate is that in case

of a breakdown to any one pump, the other pump used under heavy load will be able to perform the duty while the broken

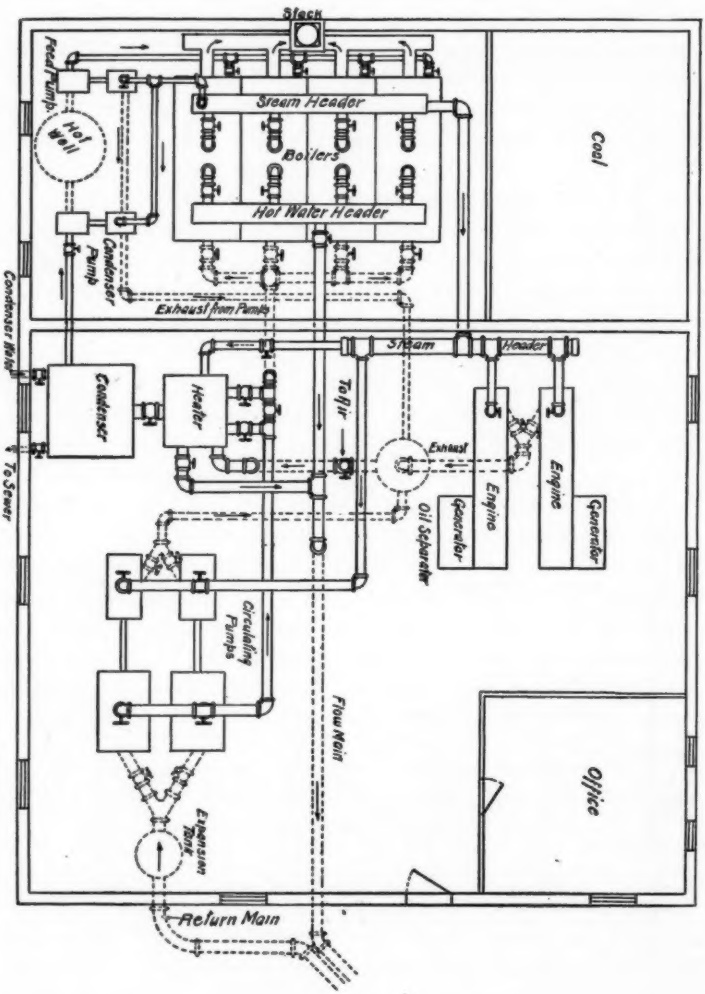



FIG. 2.

one is being repaired. It seems reasonable to assume that each pump should have a capacity of about three-fourths of the maximum requirement of the system. This would make

both pumps operated jointly to have a total value of 50 per cent. excess over maximum requirement. Applying these assumptions, we would have each pump capable of supplying 1,800,000 gallons each twenty-four hours, or 21 gallons of water per second. Since pumps are usually rated by the million gallons delivered every twenty-four hours, the rated capacity of each pump installed would probably be 1¾ million gallons. The sizes of the pumps would naturally be taken from the sizes guaranteed by the various manufacturers.

6. *Reheaters.*—In the general layout of the plant the reheaters should be located close to the pumps and on the high-pressure side. These reheaters will be of the surface type similar to a surface condenser, and may or may not be installed in duplicate. In any case they should be so piped that a part or all of the water in the systems may be passed through them as necessity requires; also that the exhaust steam which is piped from the engine will have proper drip connections to a condenser pump. The condenser should deliver the water of condensation as indicated to the boilers as feed water or to the heating system.

Assuming only one reheater to be installed, and knowing the amount of steam that will be given off from the engines per hour, the following important features may be determined: First, the size of the water pipe leading to and from the reheater; second, the number of square feet of heating surface in the reheater; third, the size of the pipe for steam connections; and, fourth, the size of the pipe for the water of condensation.

For our design assume an average lighting plant having a maximum engine capacity of 320 H. P., using, say, 30 pounds of steam per H. P. hour, or a total of 9,600 pounds of steam per hour. In a plant of this size there would also be pump service valued from 10 to 15 per cent. of the engine capacity, but in this case only engine service is considered. Steam under a pressure of 19 pounds per square inch has a total heat above zero of 1,182.62 B. T. U.* The temperature of the steam is 225 degrees, and the temperature of condensation is 212 degrees. We have then 970.62 B. T. U. given up per pound of steam,

* Figured from live steam conditions.

making a total of 9,317,952 B. T. U. per hour. On the water side of the tubes the circulating water will, according to previous assumptions, enter at about 150 degrees Fahr. and leave at 180 degrees Fahr., taking up as it passes through the reheater 30 B. T. U. per pound of water. From this we find 310,598.4 pounds of water per hour needed to absorb all this heat. Since 1 cu. in. of water at 180 degrees Fahr. weighs .035 pounds, we have 8,874,240 cu. in. of water passed through per hour. If the velocity of the circulating water is taken **at** 5 feet per second in the feed and delivery pipes the diameter would be 8 inches. To obtain the best service from the plant it would be well to have the water pass through the reheaters and pipes as slowly as possible. Since it would be necessary to put in an 8-inch pipe to obtain a 5-foot velocity, it might be well to increase this to 10 inches, the same as the outside main and permit the passage of all the water of the system through the reheater at a velocity of 7 feet per second. This might be necessary in case of any breakdown to the heating boilers, in which emergency live steam can be added to the exhaust steam in the reheater to make up the deficiency for the supply of heat.

Concerning the best velocity of the water in the reheater itself there may be more difference of opinion; probably 4 feet per second will give the best results. From this the free area of the tubes would be 134 square inches. If the tubes be taken ¾ inch outside diameter with the thickness of 17 S. W. G. and arranged as shown in Fig. 3 it will require 425 tubes and a shell diameter of approximately 30 inches.

To obtain the *heating surface* of the tubes we should know the rate of heat transmission through them. This is not easy to do since the clean tube will be much more efficient than the one that has seen some service. For clean tubes and volumes of water less than 1,000 pounds per square foot of heating surface per hour, Carpenter quotes, page 89, 427 B. T. U. per degree difference in temperature. Since the *average* heater tube is seldom capable of delivering more than 50 per cent. of the maximum transmission it will be so considered in this case. With a temperature of the steam in the reheater at 225 degrees and the average temperature on the water side $(180 + 150) \div 2 = 165$ degrees, we have 60 degrees difference between the temperatures of the two sides. From this the heat-

ing surface may be obtained for the heater from the formula

$$H.S. = \frac{\text{Total heat given up by engines per hour}}{\text{Heat transmitted through 1 sq. ft. of surface per hour}}.$$

Substituting, we have $9,317,952 \div (427 \times 5 \times 60) = 727$ sq. ft. This would be equivalent to 2.27 square feet of surface for each engine horse-power. If the inner surface of the tube be taken as the measurement of the heating surface and the total

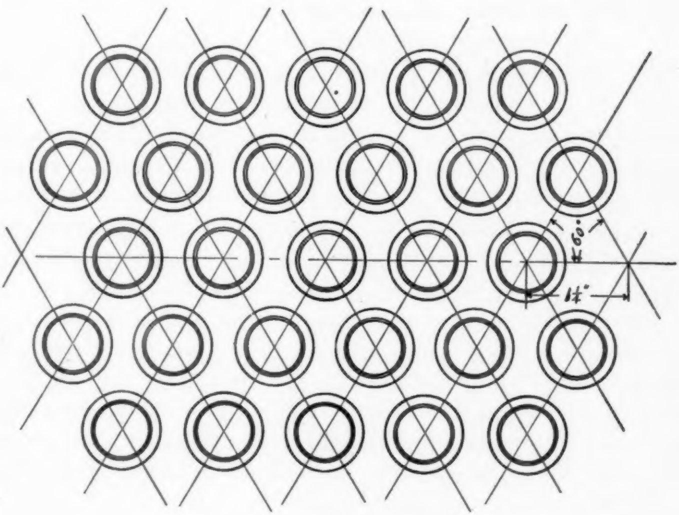



FIG. 3.

surface be 727 square feet, the length of our reheater tubes would be 10 feet.

Checking the heating surface with Whitham's "Steam Engine Design," page 283, we have for very similar conditions 1,083 square feet. Also, in Sutcliffe's "Steam Power and Mill Work," page 512, we find that condenser tubes set in the ordinary way have a condensing power equivalent to an absorption of 13,000 B. T. U. per sq. ft. per hour when the condensing water is supplied at 60 degrees and rises to 90 degrees, a difference of 30 degrees as in the preceding cases. This rate of transmission will give 716 square feet of surface. The same

reference, however, says that although 13,000 B. T. U. per square foot per hour may be easily transmitted under favorable conditions, it is wise to design only for the transmission of 10,000 B. T. U. per square foot per hour, which will give a greater margin for the use of water at a higher temperature. With a transmission of 10,000 B. T. U. per hour, we have 932 square feet of surface or nearly 3 square feet of surface for each horse-power of the engine.

An empirical formula for the amount of heating surface in a heater may be taken from a book of the International Correspondence School, which is as follows:

$$S = .0944W$$

where $W$ is the total weight of the steam used per hour. This gives 906.2 square feet, checking very closely with 3 square feet of surface for each horse-power.

Summing up the formulas as stated, it seems best to recommend the use of 2.5 square feet of heating surface per horse-power when using steam at 30 lb. per horse-power hour.

The diameter of the *exhaust steam pipe* leading into the reheater may be taken from the formula in Carpenter, page 284, where

$$d = \sqrt[5]{\frac{H P^2}{1.23}}.$$

This gives the diameter of the exhaust pipe 10 inches.

The diameter of the pipe leading to the condenser pump will naturally be taken from the catalogue size of the pump installed. This pump would be selected from capacities as guaranteed by the respective manufacturers and should be capable of handling the amount of water that is condensed from the engine.

The reheater may also be provided with a *live steam inlet* to be used when the exhaust steam is not sufficient. High-pressure steam is then used through a reducing-pressure valve. A 1½-inch pipe will probably suffice. There is some question concerning the advisability of doing this. Some prefer to install a small-sized reheater for live steam to be used independently of the exhaust-steam reheaters. This permits the use

of high-pressure steam without in any way affecting the back pressure on the engine.

An exhaust-steam reheater can be used with either condensing or non-condensing engines. With condensing engines it is placed between the engine and the condenser. During a good portion of the season, when the outside temperature is fairly high, a low temperature is maintained on the circulating water, say 130 degrees to 140 degrees, and a fairly high vacuum 18 to 20 inches can be maintained on the engine. During severe weather the vacuum may not run above 12 to 15 inches. In such cases the engine may be run non-condensing if desired. On warmer days, when but a little heat is required, or in the summer time when it is cut off entirely, the engine will be running with an ordinary vacuum of, say, 26 inches. In most cases, such plants are installed non-condensing. Steam is then used at a higher temperature in the reheater than when run condensing and requires less tube surface. During the heating season, when the exhaust steam is used for heating purposes, such an engine gives better service than a condensing engine run at varying degrees of vacuum; however, on the other hand, in the summer time the exhaust steam will be largely thrown away.

It has been the experience of some who have operated such plants that when more heat is needed than can be supplied by the exhaust steam the advantage lies with heating boilers, and when these are in good condition a greater degree of economy may be found in them than in turning live steam into either the exhaust or the live steam reheaters.

7. *Feed Water Heaters.*—In connection with the reheaters for the circulating system a feed-water heater will also be put in if the plant is non-condensing. This feed-water heater may or may not be used during the winter time, but in the summer time, when the heating system is not in use, it would serve to heat the feed water for the boiler. Exhaust steam from the engines must then connect with both the reheaters and the feed-water heater.

8. *Oil Separators.*—An oil separator must be placed between the engine and the heaters to remove as much of the oil as possible from the exhaust steam before it enters the heater. The size of the separator may be taken directly from the manu-

facturers' catalogues. Care should be exercised in selecting the type of separators, because the efficiency of the heater depends largely on keeping the surface of the tubes free from oil and scale. In some systems two oil separators are used instead of one. In no case is it possible to take out the entire amount of oil, but with a good arrangement of the system more than 95 per cent. should be removed.

9. *Boilers.*—A number of boilers will necessarily be installed in a plant of this kind, and a good scheme is to have them so piped with water and steam headers that any number of the boilers may be used for steaming purposes and the rest as water heaters. They should also be so arranged that any of the boilers may be thrown out of service for cleaning and still carry on the work of the plant. By doing this the boiler plant becomes very flexible and each boiler an independent unit. Any good water-tube boiler, such as the Babcock and Wilcox, Stirling, Wickes and others that might be mentioned, would serve the purpose both as steaming and heating boilers. Where the boilers are used as heaters, the water should enter at the bottom and come out at the top. Where the water enters at the top and comes out at the bottom, the excessive heating of the front row of tubes retards the circulation of the water in these tubes because of the natural draft given to the water by this heat, and produces a heavy circulation through the rear tubes where the heat is the least. This heavy circulation in the rear tubes is not a detriment, but it is less needed in this row of tubes than in the front ones. It would be decidedly better if the heavy circulation were in the front row, causing the heat from the fire to be carried off more readily, and by this means giving less danger of burning the tubes. With a downward circulation it has been found that the front rows of tubes soon burn out and have to be replaced. As stated above, the water should enter the bottom and come out at the top, in which case the circulation through the front row, where the fire is hottest, is greater than in the rear row, because the forced circulation from the pumps is aided by the natural circulation from the heat. The life of all the tubes then becomes more uniform.

10. *Economizers.*—Another method of reheating the circulating water is to pass it through pipe coils located in the

smoke passage between the boiler and the stack. This is called an economizer. Knowing the temperature of the stack gases, the area of the economizer surface may be estimated as in the reheaters. The amount of coil surface in an economizer, however, is more often decided by other things, such as the location and the cross sectional area of the smoke passage than from the theoretical calculations. It is never advisable to seriously restrict the smoke flue, since a good draft is necessary. Where an economizer is installed the free area at the coils must equal the area of the unobstructed flue.

11. *Piping System.*—All piping in the power plant carrying circulating water should have long radius ells, and should be so laid that all the water may be passed through the reheater, all through the heating boilers, or a part through each according to the requirement of the system. The piping at the pumps should be so arranged that each pump may be operated independently. This may be done by connecting both pumps to the main and return through long radius Y fittings having each branch properly valved.

12. *Regulation.*—The regulation of the heat within the residences is controlled at the power plant. In most heating plants a schedule is posted at the power house which tells the engineer the necessary temperature of the circulating water to keep the interior of the residences to 70 degrees at any outside temperature. In other heating plants the regulation is by means of air carried from the compressor at the power house through a main running parallel with the water mains in the conduits and branching to each building where it is used under a pressure of 15 pounds to operate thermostats, which in turn control the water inlets to the radiators. A closer regulation is obtained in the latter system than in the former, but it is needless to say that the thermostats require careful adjustments and frequent inspections.

13. *Square Feet of Radiation that can be Supplied by One Boiler Horse Power when Used as a Heater.*—Assuming that coal would be used in the plant with a value of 12,000 B. T. U. per pound, and that the efficiency of the boiler be 60 per cent., each pound of coal will transmit to the boiler 7,200 B. T. U. Since each pound of water takes up 30 B. T. U. on its passage through the heating boiler, one pound of coal will heat 240

pounds or 28.8 gallons of water. This is equivalent to supplying, under extreme conditions of heat loss, 28.8 square feet of radiation. In condensing, low-pressure steam gives up approximately its latent heat, or about 966 B. T. U. per pound, and since each boiler horse-power is equivalent to 34.5 pounds of water evaporated at atmospheric pressure, we have one boiler horse-power equal to 33,327 B. T. U. Now since each pound of coal transfers to the water 7,200 B. T. U., one boiler horse-power would require $33{,}327 \div 7{,}200 = 4.63$ pounds of coal. One pound of coal we found to supply 28.3 square feet of radiation, consequently one boiler horse-power would, from the above figures, supply $4.63 \times 28.8 = 133.24$ square feet of radiation. Boilers are usually estimated for service per each 100 H. P., consequently a 100 H. P. boiler would supply 13,324 square feet of water-heating surface.

These figures have reference to boilers under good working conditions and probably give average results. From tests made on one station of about the capacity of this one, it was found that about 50 per cent. of the entire coal fed to the heating boilers could be saved by using exhaust steam from the lighting engines in the reheaters. It would, therefore, show that a 100 H. P. boiler in connection with this one lighting plant could be estimated at about 26,668 square feet of radiation. This figure, of course, would hold good only during the time when the electric lighting engines are in full service. If boilers are estimated at the latter values it would be necessary when the lighting service becomes low to take live steam from the steaming boilers and turn it into the reheaters to take the place of the exhaust steam from the engine, or to turn one of the steaming boilers into a heating boiler temporarily. As a fair estimate of the amount of boiler service to be installed in the plant, it is suggested that enough boiler horse-power be placed to handle the steaming boiler service, and then, in addition to this, install 100 H. P. of heating boilers for each 18,000 to 20,000 square feet of heating surface carried on the lines. This gives some excess of boiler capacity, and permits one or more of the boilers to be thrown out of service temporarily for repairs and cleaning.

From the above figures our plant will require, exclusive of pumps and smaller pieces of machinery, 800 H. P. boiler ser-

vice. This may be installed in three units of 275 H. P. each, or in four units of 200 H. P. each.

14. *Cost of Heating from a Central Station.**—It will be of interest in this connection to estimate the actual cost in supplying heat to one square foot of hot water radiation per year from the average central station. In doing this make the boiler assumptions as above. Take coal at 12,000 B. T. U. per pound with a boiler efficiency of 60 per cent. and coal at 2,000 pounds per ton. Water enters the boiler at 150 degrees from the returns, and is delivered to the mains at 180 degrees. From the value of the coal as stated, we would have 14,400,000 B. T. U. per ton given off to the water. This is equivalent to heating 480,000 pounds, or 57,554 gallons of water. If one ton of coal costs, say, $2.50 at the plant, we have

$$250 \div 57{,}554 = .0043 \text{ cents.}$$

This represents the amount paid to reheat one gallon of water, or to supply one square foot of heating surface one hour under extreme conditions. Take an average temperature for the seven cold months at, say, 32 degrees Fahrenheit (figured about as follows: October, 50 degrees; November, 30 degrees; December, 15 degrees; January, 10 degrees; February, 20 degrees; March, 40 degrees; April, 60 degrees), we then have an average difference between the inside and outside temperatures in any residence of $70 - 32 = 38$. This makes the formula for the heat loss reduce to $38 \div 70 = .54$ of its former value. Now if it takes one gallon of water per square foot of radiation per hour under maximum conditions, we have for the seven months $.54 \times 7 \times 30 \times 24 = 2{,}722$ gallons of water needed for each square foot of radiation per each heating year. This is equivalent to $2{,}722 \times .0043 = 12$ cents per square foot of radiation for the heating year of seven months,

Where the plant is working under the best condition this figure should be reduced. It can be done with boilers of a higher efficiency than that stated, and it can be done by using a cheaper coal, both of which are possible in many cases.

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* Taken on basis of coal supply only.

## DISCUSSION.

The Chairman: Now, proceeding with the discussion on this paper, we have two written discussions on Professor Hoffman's paper. I will ask the Secretary to read those.

The Secretary: The first is a discussion by Professor Kent. He asks, "Why is 7 feet per second taken as the velocity of water in pipes at the power plant instead of some other figure, and why 5 feet in the outlying mains?" He also says, "Page 14, Heavy circulation; should this not be 'rapid'?" Here are two other questions:

"Query: What is the best system of covering pipes and of making conduits for pipes for central heating stations?"

"How do you figure the probable loss of heat in transmission from a central power station to the point where the hot water is used for heating?"

Here is a discussion from Mr. H. J. Barron. (The Secretary then read the following written discussion on Mr. Hoffman's paper, by Mr. H. J. Barron.)

Mr. Barron: I question the word "success" in Professor Hoffman's valuable paper. I think engineers to-day feel that it is difficult to make central-station heating pay, and yet they think that this ought not to be so; I propose taking the attitude of believing that before long there will be such improvements that heat will be successfully and cheaply distributed by wire as power and light are now, and that pending this advance in many cases it is better to use exhaust steam supplemented with live or its equivalent than hot water. The *Electrical Review* of June 24, 1905, has what I would call a symposium on this subject. Mr. Jas. E. Pyle, one of the contributors, describes a steam system with small pipes and graduated valves that is interesting.

In the *Street Railway Journal* of May 27, 1905, page 934, descriptive of The System of the Bloomington and Normal Railway, Electric and Heating Co., Mr. C. H. Robinson describes the Yaryan hot-water system.

The secret of the success of the hot-water system is the pump, and I would suggest that the same be applied to circulating exhaust steam, of course using a gas compressor; this would allow the use of very small pipes.

I want to say here that Professor Hoffman will find that his

paper does not "initiate," as this subject was covered by Mr. W. H. Bryan in Vol. VII. (year 1901) of our Proceedings. Progress generally, I have to admit, seems to be in the direction of hot-water circulation by means of a pump, the exhaust passing through hot-water heaters similar to closed feed-water heaters; the main pipes for the plant supplying 100,000 square feet of radiation are 10 inches supply and return, the pressure on the supply being from 50 to 75 pounds, and on the return one-half of this; practically the same as Professor Hoffman's design. It seems to me that exhaust steam, directly pushed into the heating mains with a positive forced blast blower similar to a cupola blower up to 75 pounds (see Innes on Fans), or an air compresser, ought to give better results, or in lieu of this, the vacuum system. If exhaust steam was put through an economizer (not the cheap design the Professor describes) on its way to the mains and superheated and then circulated on the vacuum system, the radiation supplied being merely the condenser for the system, I believe this would show economy, even by throwing away all the returns, as experience seems to show that it is not expedient to return the condensation in a central-station heating plant.

I believe there is no difficulty about taking all the exhaust from the engines, putting it through an economizer (I refer to the cast-iron economizer with scraping mechanism), and reheating it with the waste gases and sending it out from the station for both heating and power purposes. If 150 pounds pressure is carried on the boilers, steam at 75 pounds can be sold to consumers. The exhaust can be taken from the engines and compressed into the economizer, or it can be taken from the economizer and forced into the mains for distribution. The work of compression in either case costs nothing. (Notice, I say the work.)

Every gas engineer knows that compressing the charge in the gas engine costs nothing, and every air engineer knows that the work of an air compressor is stored in the fluid compressed, and therefore costs nothing. This advantage of being able to sell power at ordinary working pressure as well as heat is well worth considering. The method here proposed is better than the hot-water system under pressure tried in Boston extensively some years ago. The water was there heated in boilers and put

under such a pressure with pumps that when it was released it flew into steam at ordinary working pressures.

It is possible that the reheating of the exhaust could best be done when the gases have only partly gone through the boiler, or that designs of boilers in which the gases escape at a comparatively high temperature would be necessary, but that is a mere detail.

Professor Hoffman certainly has waked up to the fact that this field is important, but save us from home-made economizers of the pipe-coil type; they cause no end of trouble, they fill up with dirt and give out in a short time, and they are never efficient. The cast-iron economizer is almost perfect.

Possibly central station distribution will develop in this way; steam of excessively high temperature will be used primarily in the ordinary reciprocating engine, and the exhaust from the last of a series of such engines, instead of going to the condenser, will go to a Siemens regenerative re-heater as used by Professor Rateau and from thence to turbines and condenser, and the power and heat distribution will be all by wire.

I recently came across a problem of using the exhaust from a number of large gas engines in a central-station plant by means of an economizer, using the water for a central-station heating system. If the Professor had proposed taking waste gases from large blast furnaces through a set of economizers and using the water for a central-heating station circulating pump system, I would agree with him, but this problem requires caution to gain anything like success.

Mr. Schott: I think if Mr. Barron would carry his plan down to a practical basis instead of dealing with a theoretical basis he would find when he got through that he had spent from 25 to 40 per cent. more power in the compression than by directly turning the steam into the main. I had that idea several years ago, and I found I had to expend 2,500 horse-power in order to deliver 1,600 horse-power to the customer.

The Chairman: Any further discussion? Mr. Hoffman, will you answer the question, or will you wait and submit a written answer?

Mr. Hoffman: In answering Professor Kent's question as regards velocities 5 and 7 feet per second, I would say that I obtained those velocities by estimating the flow of water in the

mains of existing plants. They consequently have no theoretical foundations so far as this paper is concerned.

In Section 9, Professor Kent questions the word "heavy" as applied to circulation of water, and suggests the word "rapid" instead. I believe this is a good suggestion.

Reviewing the discussion by Mr. Barron, I think that he misunderstands the object of the paper. It was the intention to discuss the principles involved in the design of one plant rather than to make comparisons between various plants. It seems that most of the papers on central-station heating have heretofore dealt with statements of existing conditions, and did not attempt to show the reasons which have controlled these conditions. My object here is to develop a line of reasoning which would naturally be followed in the production of any one plant of the kind mentioned. In this sense only has the word "initiative," Section 1, been used.

As regards the economizer, I am sure that any brief statement such as may be given here would not be very satisfactory. The subject is a very comprehensive one and comprises many forms of design. In each type, however, the principal thing to be considered is the "amount of heating surface" necessary. This may be found in the same way as indicated under "heaters," by using varying constants of transmission for the metals involved.

Mr. Schott: I would like to ask Professor Hoffman one or two questions. You said in the plants you examined you found the velocity 5 to 7 feet per second. Is it not a fact that those plants were plants what you would term "overloaded"? They were not plants working within their normally rated capacity, were they?

Mr. Hoffman: They were plants that were working under what I considered a maximum load. In designing a system I take the maximum conditions for "heat loss" and "water supplied." For example, take the heat loss as figured during the day with zero outside temperature. Having figured from this basis, it will be necessary to provide for extraordinary conditions by increasing the temperature of the supply water.

Mr. Schott: I think you will find, as I take it from your paper there, the capacity that you specify there is about an average, not the maximum. You can take a certain amount of water radiation, if the temperature is carried as you have carried it, but when you

get down to 10 or 12 below zero, you run into something different. There is one feature that is particularly vital in a plant of that kind which you have not touched on, which is just as important as the plant itself, and that is the rules to be followed in the equipping of buildings. If you equip a building with radiation with 600 square feet of surface to do the work where you ought to have 1,000, you will be short 40 per cent., and get a 60,000 foot plant instead of a 100,000 foot plant, but have a 100,000 foot plant to operate with an income from 60,000 feet. With the velocities you have there, three feet per second, you are going to have a system that costs money to operate.

Mr. Hoffman: The temperature I assumed for the water leaving the re-heaters (or the water leaving the boilers) was 180 degrees. This gives a chance to raise the temperature to 212 degrees if you wish. This would increase the capacity of the plant (since a drop of 30 degrees only was allowed) over 100 per cent. The figures given check very closely with the Lafayette plant, which is now carrying easily 110,000 square feet of heating surface.

Mr. Schott: I can see through the whole paper: the Lafayette test, because we turned it over to the University there, gave them all the freedom and assistance we could. But some of the conditions existing the first year under the light load do not now exist. Taking a plant light loaded, as compared with one heavy loaded, and you will find that your efficiencies change very rapidly as you get high velocity in your circulating water. Using the minimum outside temperature, you get the minimum drop in your mains due to the more rapid circulation in the mains. That has to be considered. In giving the capacity of the plant you must take the minimum outside temperature; we figure it 100 degrees differential, because the difference between 70 and the temperature you get and the allowance for windage will require that. I think you will be short when it comes to maintaining an average of 70.

Mr. Hoffman: I have still another plant in mind that was tested two years ago. It was designed to supply 0.6 gallons per square foot per hour. They were giving at that time fairly good service, and it was below zero on the outside temperature.

Mr. Schott: They did one good job, if they heated that with radiation; there is where they all fall down.

Mr. Hoffman: Well, I agree with you that this is an important point.

Mr. F. N. Jewett: It is obvious that the capacity of the mains of a forced circulation system depends upon the head or pressure produced by the circulating pump. I am acquainted with one central-station heating plant at Marion, Indiana, where a 7-inch main pipe has carried satisfactorily 110,000 square feet of radiation in weather 15 degrees below zero, with circulating pressure of 42 pounds.

Mr. W. H. Schott: Forty-two pounds differential?

Mr. Jewett: Yes.

Mr. Harvey: I would like to ask some of these gentlemen if they know of any first-class central heating plant that has paid any dividends after the first five years?

Mr. Schott: I will answer the gentleman's question. I would like to say that out of 250 steam plants built in the United States very few of them have been dividend payers. Out of 75, or approximately that number of water plants it has been very hard to get statistics, due to the fact that they have slipped their heating income in with their electric lighting. There is only one central plant on the water basis that is operating on a fuel basis, and that is at Terre Haute; this has been in operation one year. That plant took care of its interest on the bonds and paid three per cent. upon its stock the first year. It is expected that it will pay 8 per cent. next year. Their coal on track costs 85 cents a ton. Coal to the wholesale consumer costs from $2 to $2.25, assuming he uses soft coal. If he consumes hard coal it costs from $7.50 to $9. The price for radiation is based upon $9 for hard coal. They have carried their business the past year on coal at 85 cents a ton; it costs 5½ cents per square foot for fuel; charging 17 cents per square foot. Charging 17 cents with the plant loaded 60 per cent. of its capacity, it is costing 8 cents per square foot; you have a differential of between 8 and 17 to take care of the capital account. The capacity of the plant is 400,000 feet. The cost per square foot of the plant when it is fully completed will not exceed 60 cents per square foot; so that 60 cents per square foot is the capital account, and with 9 cents to come and go on, you can see where the dividends are going to come in. If you have $3 coal you have to raise the price accordingly.

The idea that you can sell heat at 12 or 15 cents per foot regardless of fuel conditions is wrong; you cannot do it.

Mr. Harvey: I have seen a good many cases that you could figure out on paper; I have seen a good many plants started, and I think they pay dividends for the first few years; but I supposed it was like a lot of other stock operations, it was done from the proceeds of the stock, not from the proceeds of the earnings of the plant. That was why I asked the question if any gentleman knew of a plant that had been running five years, when their surplus money has been used up. There are some repairs that have to be paid for, and so forth. I just wanted to know from those most interested if they could cite some case where there had been a profitable investment with a running plant.

Mr. Jewett: At Red Oak, Iowa, the Electric Light Company installed six years ago a central-station heating plant, using the exhaust steam from the electric light engines for heating the water in the system.

Red Oak is comparatively a small town, having about 5,500 people. The lighting plant had been established for some years previous to the installation of the heating plant. The original cost of the heating system was about $15,000. That represents capital account.

Within two years from the establishment of the heating plant the gross revenue from heating service amounted to $7,500 per annum. The company's coal account was increased by about $1,000 per annum. No added labor is required. During the winter months one added man spends part of his time visiting the customers to see that all are satisfied, to pack a few radiator valves, etc. This costs about $40 per month, or for 7 months = $280.

So, leaving out of account interest and depreciation, the operating expense chargeable to the heating system amounts to less than $1,500 per annum.

This leaves about $6,000 for interest, depreciation and repairs, a handsome showing on the investment. The plant has been in for six years, and up to the present no repairs worth mentioning have been found necessary.

Mr. Schott: Take a modern central station such as are being built to-day and there is no reason why the depreciation account should not be within four per cent. There is no question but

what if a power plant is built in conjunction with some other industry, which has a large volume of exhaust steam, that it betters the enterprise, due to the utilization of the waste. But prices for heat, and every detail, to be certain, ought to be founded just the same as if it was on its own bottom. In other words, the proposition ought to be good enough to stand on its own bottom. That is what we have been fighting for for the last five or six years, the thing we have been trying to establish, and the thing we are going to establish, and that is that the central heating plant will stand on its own bottom, and take care of itself if you build your plant right and take care of your people right, because that is what you make success with. You may take a building and equip it properly, and for the time being you may obtain fair results, but if properly equipped from the beginning, and put on the proper basis, your returns will be much greater. There is no proposition, no industry that is more staple, and after the first year, when you do the hustling and satisfy your customers that the plant is all right, then they will do the talking for you.

Mr. Davis: Answering Mr. Harvey's question, I will say I know of a plant that has been in operation several years and it has never paid less than 8 per cent. dividends, the Consumers' plant at Bloomington, Ill. I assume and know that it is somewhat due to the fact that they furnish power as well as heat, and they will not furnish a man heat unless they have his lighting. But they have never paid less than 8 per cent.

# CXLVII.

## DRYING BY STEAM, HOT AIR AND WASTE GASES.

BY HUGH J. BARRON.

It may be possible that, in the future, electrical drying will supersede other methods, but as we are in and part of the transition period, we will confine ourselves to those methods which have been developed in the last hundred years. I recall, while working as a fitter's helper or apprentice in the large woollen mills around Philadelphia thirty years ago, that the large drying rooms had large 1-inch trombone mitre coils extending over the floor area. These coils were about 20 feet long, with mitres about 2 feet, and were about 15 pipes wide. The shoddy and other material to be dried was placed over the coils, 60 pounds of steam being used in the coils, which was considered high pressure at that time.

This was not an economical method. As a matter of fact, drying does not lend itself to economy. It is, in most cases, rather wasteful, but there is no reason why it should be uneconomical, except that the art is more or less of a side issue with those who should be experts in its development.

The matter of this paper was suggested by a talk I had recently with one of the ex-presidents of this society. He said that one of his customers had determined to install exhaust fans in his cloth-drying room. He advised him strongly not to use exhaust fans for the purpose, as, in his opinion, the proper way to dry material like wet cloth was to force warm air into the drying room; that where disc fans were used to exhaust the air in connection with direct heating coils, the leakage of air through the walls and around the windows nullified the drying effect by reducing the temperature of the air in the room. He further said that it was noticeable wherever this latter system was used that the drying rooms had wet floors,

whereas, where the air was forced in hot, the moisture was carried entirely out of the ventilators.

The problem is to force a certain volume of air into and out of the drying room, changing the air in this room every five to ten minutes, the temperature of the air as well as the rapidity of the change depending upon the moisture and the outside atmospheric conditions.

The primitive manner of drying all material is by exposure to the sun, and, in most processes of manufacture, the best results are produced by open-air drying. This is particularly true of leather tanning.

Baldwin, in his book "Steam Heating for Buildings," page 188, fourth edition, says:

> "It is not profitable to dry by forcing air, as with a fan or blower, in connection with steam coils."

This was said a little over twenty years ago. Since then, drying by fan blowers has practically superseded all other methods.

In Babcock & Wilcox's catalogue "Steam," it is stated:

> "The philosophy of drying or evaporating moisture by heated air rests upon the fact that the capacity of air for moisture is rapidly increased by rise in temperature. If air at 52 degrees is heated to 72 degrees, its capacity for moisture is doubled and is four times what it was at 32 degrees.
>
> "For each 15 pounds of water required to be evaporated per hour in a drying room, one horse-power of boiler, 130 square feet of steam pipe and 14,000 cubic feet of air are required under good conditions."

In the twenty-first edition of this book, 1896, there is added a table, which gives the weight of a saturated mixture of air and aqueous vapor at different temperatures up to 160 degrees, together with the weight of vapor, in pounds and percentage, and total heat, the portion contained in the vapor and the quantity of air required per pound of water.

SATURATED MIXTURES OF AIR AND AQUEOUS VAPOR.

| Temperature, Deg. Fahr. | Weight of 100 cub. ft. of mixture in lbs. | Weight of water in 100 cub. ft. of mixture in lbs. | Per cent. of water in mixture. | Heat units in 100 cub. ft. of mixture. | Per cent. of heat in vapor. | Dry air required for vapor in mixture. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lbs. | Cub. ft. |
| 35 | 8.004 | 0.034 | 0.42 | 42.8 | 86.69 | 234.4 | 3,060 |
| 40 | 7.920 | 0.041 | 0.52 | 59.8 | 76.59 | 192.2 | 2,526 |
| 45 | 7.834 | 0.049 | 0.62 | 77.7 | 68.98 | 158.9 | 2,068 |
| 50 | 7.752 | 0.059 | 0.76 | 97.6 | 66.29 | 130.4 | 1,714 |
| 55 | 7.668 | 0.070 | 0.91 | 118.3 | 64.58 | 106.5 | 1,326 |
| 60 | 7.589 | 0.082 | 1.08 | 140.1 | 64.31 | 91.6 | 1,208 |
| 65 | 7.507 | 0.097 | 1.29 | 164.9 | 64.76 | 76.4 | 1,004 |
| 70 | 7.425 | 0.114 | 1.49 | 189.7 | 66.21 | 66.0 | 868 |
| 75 | 7.342 | 0.134 | 1.79 | 221.6 | 66.74 | 55.0 | 723 |
| 80 | 7.262 | 0.156 | 2.15 | 253.6 | 68.02 | 45.6 | 599 |
| 85 | 7.178 | 0.182 | 2.54 | 289.7 | 69.66 | 38.4 | 505 |
| 90 | 7.108 | 0.212 | 2.98 | 330.2 | 71.19 | 32.5 | 427 |
| 95 | 7.009 | 0.245 | 3.50 | 373.4 | 72.87 | 27.6 | 363 |
| 100 | 6.924 | 0.283 | 4.08 | 422.0 | 74.58 | 23.5 | 308 |
| 105 | 6.830 | 0.325 | 4.76 | 474.7 | 76.22 | 20.0 | 263 |
| 110 | 6.741 | 0.373 | 5.23 | 533.9 | 77.88 | 17.1 | 224 |
| 115 | 6.650 | 0.426 | 6.41 | 599.1 | 79.52 | 14.6 | 192 |
| 120 | 6.551 | 0.488 | 7.46 | 672.4 | 81.14 | 12.6 | 163 |
| 125 | 6.454 | 0.554 | 8.55 | 750.5 | 82.62 | 10.7 | 140 |
| 130 | 6.347 | 0.630 | 9.90 | 839.4 | 84.13 | 9.1 | 118 |
| 135 | 6.238 | 0.714 | 11.44 | 936.7 | 85.57 | 7.7 | 102 |
| 140 | 6.131 | 0.806 | 13.14 | 1,042.7 | 86.80 | 6.6 | 87 |
| 145 | 6.015 | 0.909 | 15.11 | 1,160.6 | 88.18 | 5.6 | 74 |
| 150 | 5.891 | 1.022 | 17.33 | 1,288.4 | 89.39 | 4.8 | 63 |
| 155 | 5.764 | 1.145 | 19.88 | 1,427.4 | 90.53 | 4.0 | 53 |
| 160 | 5.679 | 1.333 | 23.47 | 1,638.7 | 91.93 | 3.3 | 43 |

By an inspection of this table, "It will be seen why it is more economical to dry at the higher temperatures. The atmosphere is seldom saturated with moisture, and in practice it will be found generally necessary to heat the air about 30 degrees above the temperature of saturation."

I am inclined to believe that in any drying problem the important fact is to get the saturation of the material, the amount of water per pound or per ton it contains, then to figure the number of heat units necessary to vaporize this moisture, which approximates the latent heat of steam at 212 degrees, 965 B. T. U. per pound of moisture and then to supply a volume of air containing these heat units which will absorb the required volume of moisture or water.

In an article on Drying Rooms, by J. L. Bixby, Jr., published in "Heating and Ventilation," December, 1895, the author says:

> "The philosophy of drying is the fact that heated air will absorb moisture as a sponge absorbs water. When air has taken up all the moisture that it can, it is said to be saturated. Air charged with vapor is lighter than air not

so charged. Damp air has 85 per cent. moisture; moderately dry air, 65 per cent.; dry air, 50 per cent.; very dry air, 35 per cent.; extremely dry air, 25 per cent. For each increase of 27 degrees in temperature, its drying capacity is doubled. For laundry work, 130 degrees is most satisfactory. Five hundred feet per minute is the proper velocity of air in drying rooms. Exit and inlet should be located at the floor line of the drying room. The radiation required for drying rooms is 1 square foot to each 3 cubic feet of space. When hot water is used, the radiation should be doubled. For fresh air supply, allow 2 square inches per square foot of heating surface, and for exit openings 50 per cent. additional. Clothes after wringing average in weight one pound to the square yard. For screening the air supply to drying rooms, cotton cloth screens should be used."

Some lines of drying, like laundry and lumber drying, have become stereotyped and the lines of practice are well established. Other lines are in the experimental stage and new developments in manufacture are constantly bringing up new problems.

A great deal of time and money has been spent in experimenting with brick drying in connection with machine brick making. Until recently, large massed box coils were placed in the bottoms of the tunnels and the brick cars were passed over them. High-pressure steam was used in the coils and the tops of the tunnels had ventilators. This was supplemented by exhaust fans forcing in air at the wet end or entrance. At the present time, brick drying is almost entirely hot blast, a blowing fan and stack forcing hot air into the tunnels. One of the trade catalogues referring to a brick-drying tunnel states:

"The end of the dryer opposite the heater is termed the green or wet end. Into this end the cars are rolled when filled with fresh soft bricks. If at this stage they were subjected to the high temperature of the heater end, cracking and warping would take place. Not until part of the moisture is removed and the bricks prepared for increase of temperature are they moved forward towards the other end. The space thus left is filled with cars of

fresh brick, making the process continuous. A single tunnel 100 feet long, 5½ feet wide by 5½ feet high, will dry 10,000 stiff mud bricks every twenty-four to forty-eight hours, nearer forty-eight than twenty-four, depending largely on skill and management."

In regard to tobacco drying, Baldwin states that to be effective it requires direct heating from coils. The average tobacco factory in the north, however, depends upon hot blast heating in the drying room.

The following extract is taken from an article on "Steam Engineering in Paper Mills," by E. S. Farwell, published in "Cassier's Magazine" for May, 1905:

> "The ventilation of the machine room is an unusually important problem. For every ton of paper made, two tons of water must be evaporated and carried off by the air of the room before it condenses on the cool surfaces. There are often two machines in each room, each making a ton or a ton and a half of paper every hour.
>
> "One pound of air at 132 degrees temperature will carry 0.1177 pound of water at saturation, or at 80 per cent. saturation about 0.09 pound of moisture. One pound of air at zero temperature and 60 per cent. saturation contains 0.0005 pound of water, which may be neglected. For each ton of paper made in twenty-four hours, there will be given off 166.7 pounds of water per hour, which will require 1,852 pounds or 460 cubic feet of air per minute to absorb it.
>
> "The amount of heat required to raise this air from 10 degrees below zero to 132 degrees above is found by multiplying the weight of air by 0.2375 and by the difference in temperature, or 142. In addition to the volume of air computed by this method, there must be in large rooms, having no hoods over the machines, more air provided, which, in all probability, will short circuit and not absorb its proportionate amount of moisture. Many successfully ventilated machine rooms have an air change every two to six minutes. With a properly designed system it is not necessary to change so often."

The drying rolls of such machines are generally enveloped in a hood, which is usually fitted with two 48-inch disc or propeller fans capable of exhausting from thirty to forty thousand cubic feet of air per minute. In cold weather air is forced into the machine room at a temperature of about 90 degrees, so that we have in the machine room of a paper mill what is considered the best practice to-day in heating and ventilating, viz., hot air forced in at whatever temperature required and local ventilating fans exhausting air wherever necessary to meet special conditions.

In brick drying and in some other lines of industry of a similar nature where there are kilns which waste gases of high temperature, these gases are taken up by a fan and forced through the drying tunnels or rooms. Disc fans are employed for exhausting and giving a thorough circulation to the waste gases.

In drying lumber, part of the moist air is returned to be reheated, while the very wet air is forced out of the loading end. If the lumber has been previously partially air dried, there is some saving in returning a part of the air from the kiln to the heater. It usually takes a week to dry ordinary one inch stuff, such as yellow pine.

The essential principles in all drying are large volume of air and not particularly high temperature. This is why open air sun drying is so satisfactory. In lumber drying the moisture vaporizes and passes off, but if the temperature is too high the resin in the wood will harden and, bursting from expansion, will cause checking of the wood. Where it does not do this, it is apt to leave the lumber non-elastic and brittle. The moist air which is returned is often blamed for causing this condition and also for staining the lumber.

In drying wool, cotton, silk, jute, pine fibre, rubber, etc., the material should be placed in a bed made of wire screen of almost any mesh. The screen is kept in constant motion and large volumes of air passed through it. The screen is so arranged that all the air must pass through it.

There is in almost every heating and ventilating job a drying problem.

In regard to the paragraph I quote from Mr. Farwell's article, "For each ton of paper made in twenty-four hours,

there will be given off 166.7 pounds of water per hour, which will require 1,852 pounds of air per hour or 460 cubic feet of air per minute to absorb it," it will perhaps help those who study it to call attention to the following statement in an earlier part of Mr. Farwell's paper: "The amount of steam that should be required to dry paper can easily be calculated after making several more or less uncertain assumptions." It will be fair to assume that for every pound of paper made two pounds of water must be evaporated. The temperature of the water as it comes from the presses may be assumed to be about 65 degrees; to evaporate it into steam will require 1,113 B. T. U. per pound of water. In modern machines the steam pressure in the dryers is carried at from 1 to 6 pounds. The water as it leaves the dryers will have a temperature of about 210 degrees. One pound of steam at 5 pounds pressure contains 1,183 heat units, of which it will give up 1,183-210 heat units, which equals 973 heat units. If, then, all of this heat went into the water of the paper, the amount of steam required per pound of paper would be $\frac{2 \times 1113}{973} = 2.29$ pounds. This clearly indicates one point to be carefully watched. The basic problem in all drying is merely the evaporation of so much water in the form of moisture.

In considering this, it is well to keep in mind the following:

One B. H. P. will evaporate 20 pounds of water or moisture with the blower system. One cubic foot of air at a temperature of 50 degrees will absorb 5 grains of water. At a temperature of 75 degrees, it will absorb 10 grains; at 100 degrees, it will absorb 20 grains; at 150 degrees, it will absorb 75 grains; at 200 degrees, it will absorb 200 grains. Seven thousand grains equal 1 pound. 437.5 grains equal 1 ounce. 33.305 B. T. U. equal 1 H. P. One pound of air contains 12.387 cubic feet at 32 degrees F. Thirty-three B. T. U. will warm 1 pound of air from zero to 135 degrees. One lineal foot of 1-inch pipe at 215 degrees will warm 3 cubic feet of air from zero to 130 degrees.

The engineer sometimes requires a closed air heater to utilize waste gases for drying purposes. Fig. 1 represents a late design of air heater which, in connection with a fan, will supply a large volume of air for drying purposes and utilize

gases that would otherwise be wasted. Fig. 2 is a half section, showing the top and bottom section. The headers are sloped in opposite directions, admitting of a greater opening at the sectional openings of the headers, where the largest volume of air has to pass. The air leaves the heater at the top hot end where the gases first strike the tubes.

In air heaters, I assume the transmission per square foot per degree difference of temperature is about 1.25 B. T. U. per

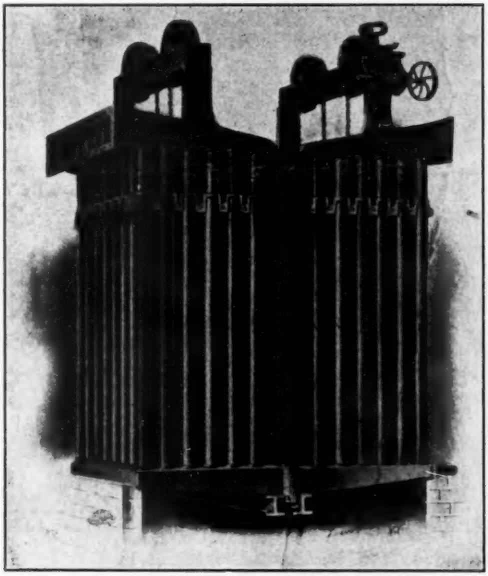


FIG. 1.

hour. In giving 1.25 B. T. U. for the transmission per degree difference of temperature, I assume that the mean difference transmission corresponds to economizer practice, the average of which is 2.5 B. T. U., and with boiler tubes at the higher temperatures is 5 B. T. U. per square foot per hour. The transmitting efficiency is still further increased, at least 50 per cent., by the air being forced by a fan through the tubes at a high velocity.

At a temperature of 32 degrees under a pressure of 29.92 inches of mercury, a cubic foot of air weighs 0.081 pound.

The volume of one pound of air at 32 degrees is 12.387 cubic feet; at 70 degrees, it is 13.342; at 212 degrees, it is 16.91; at 360 degrees, it is 20.63; at 550 degrees, it is 25.403; at 650 degrees, it is 27.915; at 800 degrees, it is 31.864; at 1,000 degrees it is 36.811; at 2,000 degrees, it is 61.04; at 3,000 degrees, it is 87.13. One pound of air at atmospheric pressure of 14.7 pounds at 3,000 degrees F. has a volume of 87 feet, so that in figuring transmission of heat between surfaces per square foot, it is important to consider the volume due to the temperature. After multiplying by the number of B. T. U. absorbed per degree mean difference, it is necessary to also multiply by the decimal .2375 in order to obtain the specific

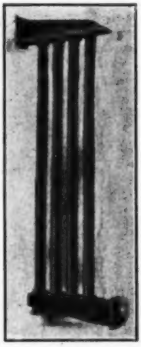


FIG. 2.

heat of air. When air is the absorbent, a B. T. U. has about three and three-fourth times the heating capacity that it has where water is the absorbent.

Specific heat of air is 0.2375 when water is unity. To heat a pound of air from any temperature A, through a given number of degrees B, to a temperature A + B, will require only 0.2375 as much heat as would be necessary to raise a pound of water through the same number of degrees.

Let us consider a room 30 feet long, 10 feet wide and 10 feet high, having a window at one end and a door at the other. In this room are hung on ordinary drying horses 400 wet woollen blankets, each blanket having about 5 pounds of water, or a total of 2,000 pounds of water to be dried out in a reasonable time. The temperature of the room and the blankets is

60 degrees. To evaporate and absorb one pound of water at 60 degrees requires about 1,200 B. T. U. 2,000 $\times$ 1,200 = 2,400,000 B. T. U. to be supplied in air. One pound of air at 90 degrees contains about 300 B. T. U., which is equal to about 14 cubic feet. 2,400,000 $\div$ 300 = 8,000 pounds of air, which is equivalent to 112,000 cubic feet, the amount necessary to dry the blankets. This amount of air per minute from a blower should dry the material in an hour, if the reasoning is correct.

If it takes only .238 as much heat to raise the same weight of air as it would to raise a similar weight of water, the air-heating surface, instead of transmitting only one-fourth as much heat with air as with water, will transmit nearly four times as much, or 10 B. T. U. per degree mean difference of temperature per square foot per hour.

Thomas H. Huxley, in his essay on René Descartes' Discourse on Method, says: "There is a path that leads to truth so surely that any one who will follow it, must needs reach the goal whether his capacity be great or small." This statement gives me hope that we will reach the correct relative transmission per degree difference per square foot of surface per hour between hot gases and cool air.

## LITERATURE ON THE SUBJECT.

In addition to the articles already mentioned, the following works bear upon this subject, taken from the Engineering Index:

Drying Coal, American Society of Mechanical Engineers, 18th vol.

Drying Paper Pulp by Hot Water, American Society of Mechanical Engineers, 8th vol.

Determination of Humidity in Drying Plants, by Paul Fuchs, Gesundheits-Ingenieur, October 31, 1899, Muenchen, Bavaria. Three thousand words.

Drying Installations, by M. Grellert, Gesundheits-Ingenieur, May 25, 1898. Twenty-five hundred words. This paper gives various methods of figuring quantities of heat required for given results in drying.

Modern Drying, the theory of air drying apparatus, Zeitschrift

des Vereins Deutscher Ingenieur, Berlin. Three thousand words.

The Principle and Construction of Drying Plants, by Prof. P. Pfeifer, Gesundheits-Ingenieur, February 15, 1898. Four thousand words.

Plumbers and Fitters Hand-Book, published by the International Correspondence Schools, Scranton, Pa., contains a useful article on drying.

Wool Drying, Scientific American Supplement Index.

Theory of Drying, Scientific American Supplement Index.

Catalogues of the numerous blower manufacturers.

Humidors for measuring the humidity should be used in all drying-rooms; I understand that Mr. Sutcliffe when he was over here from England a short time ago said he was surprised, that the art of drying as practised by us was away behind the advanced practice on the other side; I have only learned recently that there are several companies in this country making an exclusive specialty of drying.

## DISCUSSION.

Mr. Chairman: Any discussion?

Mr. Chew: Mr. President, I think it was last January we had a paper treating on humidity in connection with heating, more particularly for heating buildings to be occupied by people. It strikes me that this paper, taken in connection with that, will give some information that the other paper did not contain.

Mr. Scott: On page 9 of his paper, Mr. Barron makes the statement: "When air is the absorbent, a B. T. U. has about 3¾ times the heating capacity that it has where water is the absorbent." A literal reading of this statement would give the impression that a B. T. U. is a thing of variable capacity instead of the fixed mathematical quantity which it is supposed to be. And while from the context it is clear that Mr. Barron is referring to the differences in effect upon air and water produced by a given quantity of heat, it may still be in order to direct Mr. Barron's attention to this irregularity in description in an otherwise excellent paper.

Mr. Jewett: On page 10, the second paragraph, the writer says: "If it takes only .238 as much heat to raise the same

weight of air as it would to raise a similar weight of water, the air heating surface, instead of transmitting only ¼ as much heat with air as with water, will transmit nearly four times as much or 10 B. T. U. per degree mean difference of temperature per square foot per hour." I hardly think that reasoning will hold. If I understand him correctly, he assumes that with a sheet of metal having air on both sides, he gets 10 B. T. U. per square foot per hour per 1 degree of difference between the two sides. He can't do it.

Mr. Davis: On pages 4 and 5 the author describes a brick drying apparatus. I think the information would have been of considerably more value if he had given us some idea of the amount of heating surface that was used in drying those 10,000 bricks in 24 hours, and the quantity of air that passed through the tunnel. As it is, it is simply a statement that a tunnel dries 10,000 bricks in 24 hours, which gives us no idea of the amount of heating surface required to produce that effect.

Mr. Widdicomb: The author has mentioned in almost every instance of drying the necessity of driving air through by means of a fan; otherwise there is no mention made whatever of the principle of the Morton kiln, or any other. There can be no drying when there is no forcing of the air, and yet the drying is thoroughly done.

Mr. Scott: Along the lines of the last speaker, it may be stated that lumber drying to-day is largely done with the same air used over and over again. The heated air after passing from the region of the steam-heated coils rapidly absorbing the remaining moisture in the lumber at the outgoing end of the kiln, and giving up its vapor by partial condensation at the incoming end of the kiln, at which point a simple ventilating arrangement permits the watery vapor to escape into the atmosphere, the current of air being then deflected in the direction of the steam-heated coils, there to once more acquire, by its heated condition, an increased capacity for the absorption of moisture. This plan has almost wholly eliminated the blower practice of driving air into the kilns. Not entirely, but to a great extent.

Mr. Bailey: One of the best apparatuses for drying clothes that I know of is made by the American Laundry Machinery Company. It is simple to use and the practical results are great.

It takes the air and drives it down and passes up the side and down through the centre again.

Mr. Jewett: As I understand kilns, the water which is in the lumber must be taken out and *disposed of*. The Morton kiln does have a gravity circulation of air through flues provided in the side walls, which flues are simply chimneys running to the outside air. At certain positions inlets are provided. While the amount of air change is relatively small, yet the moisture is thus carried off and outside the kiln.

Lumber cannot be closed up in an absolutely tight box, with no air change at all, and be dried.

## CXLVIII.

# POSSIBILITIES IN HEATING WITH HOT AIR.

BY R. S. THOMPSON.

Judgment is liable to be influenced by interest, and it is natural to suppose when a person advocates any particular system of heating that he has a special financial interest in that system.

That the arguments I present may not be thus discounted, I will state that the concern with which I am connected is just as well pleased to get a contract for heating with hot water or steam as with hot air, and my opinions are, therefore, unbiassed by interest.

The primary object in all house heating apparatus is to fill the house with warm air, and in all systems the air is warmed by contact with heated surfaces, as air is absolutely transparent to radiant heat.

In heating with hot air, the air is heated by contact with hot surfaces in a central heating apparatus, and is then conveyed to the rooms. In heating with hot water or steam, the water is heated in the heating apparatus, conveyed to the rooms, and there used to heat the iron of the radiators, which in turn heats the air.

The difference between the two systems is, therefore, practically that in the hot-air system, the air is heated by one central plant, while with hot water and steam, the air is heated by a separate plant or substation in each room, which substation is heated from a central station.

It is not my purpose to disparage the system of heating the air by individual heating plants, but to show some of the possibilities in heating the air by a central plant, a system which, in my judgment, has been largely left to incompetent men, and has not received the attention and scientific study which it deserves.

That this system has been in a large proportion of cases un-

satisfactory, I freely admit, but believe that the failures have been due to errors in construction or operation and not to any inherent defect in the principle.

Heating the air by a central plant involves less expense in the installation, and this is a matter which demands the consideration of the practical engineer. Economy in first cost is not everything, but it is something, and with probably ninety-nine out of one hundred people who have homes to heat, a very vital something. While a really first-class hot-air plant cannot be installed at the prices commonly charged for inferior and inefficient ones, yet even such a plant costs less than a hot-water or steam system. Economy of first cost is, therefore, a possibility in heating with hot air.

But economy of operation is no less important. The plant is paid for once, the fuel bill is a continuing expense and frequently amounts to more in a few years than the first cost of the plant. No system is economical which involves a continuous useless expense.

What are the specific facts in regard to cost of operation in heating with hot air?

A given amount of fuel will in perfect combustion set free a given amount of heat, no more and no less. The heat is in the fuel, not in furnace or boilers. No heating apparatus can add a single unit. The theoretically perfect plant would be one in which there was absolutely perfect combustion of the fuel and complete utilization of the heat released by this combustion, and on these two points depends the comparative economy of operation.

On the first point, completeness of combustion, while there is large difference in different apparatus, there is no essential difference between the two systems. The fuel can be burned as perfectly, and as large a proportion of the heat units contained in it be released, with one system as with the other. The issue is, therefore, narrowed to what becomes of the heat after it is released from the fuel.

Heat cannot be destroyed. Once produced, it must either be transformed into some other form of energy or continue as heat. In house heating, it may be practically said that all the heat released by combustion either goes toward heating the house, that is, to replacing that which has been lost by radia-

tion and leakage through walls and windows, or escapes up the chimney, having performed no more useful function than the creation of a draft.

The extent to which the heat produced is utilized can, therefore, be practically determined by ascertaining the per cent. which escapes to the chimney. The lower the temperature at which the waste products of combustion escape to the chimney (velocity of current being the same) the larger will be the per cent. utilized for heating the house and consequently the greater the economy of operation. In other words, the extent to which the cooling of the products of combustion can be carried is the measure of the efficiency of any heating apparatus.

Let us see the theoretical limit to which the cooling can be carried, keeping in mind the fact that the theoretical limit can never be reached much less passed in practice.

The products of combustion are cooled by contact with metal which is cooled by contact with water or air. The theoretical limit of cooling is, therefore, the temperature of the air or water by which this cooling is accomplished.

With live steam, the possible minimum is the temperature of water boiling under normal atmospheric pressure, or 212 degrees.

With hot water, the possible minimum is the temperature of the water as it returns to the boiler from the radiators, usually 140 degrees to 170 degrees.

With hot air, the possible minimum is the temperature of the cold air entering the furnace, anywhere from below zero to 70 degrees.

The theoretical limit of cooling and consequent theoretical economy in operation is, therefore, lower with hot water than with steam, and lower with hot air than with either hot air or steam.

It is, therefore, possible—theoretically—to heat with hot air more economically than with any other system.

But the advocates of the other systems will contend that while this may be so in theory, yet that in practice, owing to the greater power of water to absorb heat, it is otherwise, and that actually the exhaustion of the heat contained in the prod-

ucts of combustion is carried much further in both steam and hot-water heating than it is in hot-air heating.

In many cases, I admit the contention, but in turn contend that the reason is to be found in the construction of the apparatus and not in the principle, and that it is entirely possible to so construct hot-air apparatus, that the same difference in its favor, as compared with hot water and steam, will exist in practice as is shown in theory.

A few days since I made a test with a hot-air furnace, and found the temperature in the smoke pipe was 120 degrees, or at least 20 degrees lower than the theoretical minimum with hot water, and 92 degrees lower than the theoretical minimum with steam. Probably you will say that the fire was low. Judge for yourselves. At the time I took the temperature of the smoke pipe, the furnace was delivering over a thousand cubic feet of air a minute at a temperature of 210 degrees. And when this test was made, the temperature of the outside air was 80 degrees, or at least 40 degrees higher than would be usual in the use of the apparatus. It may safely be said, therefore, that in actual practice the cooling of the products of combustion in a hot-air furnace can be *actually* carried from 40 degrees to 120 degrees lower than the *theoretical* minimum with hot water and steam.

I think it, therefore, demonstrated, both by scientific deduction and practical test, that one of the possibilities in heating with hot air is the utilization of a larger per cent. of the heat contained in the fuel than can be secured by any other system.

In heating with hot air, however, there is an expenditure of heat which may perhaps be called waste, namely, the heat contained in the air which is forced out of the building by the pressure of the warm air that is being poured in.

But this loss of heat is due to the necessity for ventilation. A given amount of ventilation will involve the same loss of B. T. U. whatever the heating system may be.

It is true, with hot-water or steam heat it is possible to reduce the ventilation below the proper ratio and thus save heat. But this is equally possible with hot air, if the plant is so constructed that the amount of ventilation can be controlled.

It is true, that with hot air heating, ventilation can be carried to a point which will involve large loss, as I shall show

hereafter. The same is true with hot water and steam. You can open the windows and crowd the fire.

But in either case, the loss is to be charged up to ventilation, or bad management, and not to the system of heating, and can be as well controlled under one system as another.

It is a possibility in heating with hot air to heat all the rooms in a house at the same time. I am compelled to admit that this is not always done in practice. I could not even dispute the statement that it is not often done, but I can demonstrate both theoretically and practically that it can be done, and that which can be done is a possibility.

The difficulty has not been in the principle, but in the apparatus, not in the gun but in the man behind the gun.

If the amount of cold air that is supplied to the furnace is equal to the amount that can be forced through all the hot-air pipes, if the construction of the furnace is such that this amount of air can pass through the casing and reach the hot-air pipes, with velocity unreduced by friction, if the furnace has the necessary surface and the necessary arrangement of surface to heat all this air, if the size and form of the hot-air pipes is such as will permit the passage of the required amount of air to each room, and if there is no serious " back pressure " in any room, the furnace will heat them all at the same time. For if enough air is being pressed through the furnace to supply all that can be carried by all the pipes, the pressure in the furnace will force this air through all these pipes, if the resistance due to friction and back pressure in the rooms is less than the pressure in the furnace. That is a simple matter of mathematical demonstrations.

There are a great many " ifs " in that claim? Certainly. And it is the business of the heating engineer to look after those " ifs." If he can't do it, he has not yet mastered his profession.

These " ifs " cannot be met either by guess work or by a set of hard and fast rules. They require a thorough scientific knowledge of the principles involved, a considerable amount of practical experience, and a liberal use of horse sense.

Air is compressible and elastic. It is subject to friction, inertia, and momentum. The fact that two pipes have the same area is not proof that the same pressure will force the same

amount of air through each. To get proportions correct is not a simple or easy matter, but requires the exercise of brains and judgment.

It is possible in heating with hot air to heat those rooms which are most exposed to the wind, or the windward side of large rooms. The course of heated air is subject to definite laws, and by the use of these laws it can be controlled. But the man who would control it must make himself familiar with these laws and not content himself with a lot of empirical formulas.

The cause of trouble in heating rooms exposed to the wind is that the air pressure on the outside by leakage produces air pressure in the room, and if the pressure in the room is greater than the pressure in the pipe, the greater will overcome the less. If the pressure of air on the outside is so great that the pressure of air in the pipe cannot force air out through the crevices around windows, and there is no outlet for the air, it will be impossible to force air into the room and consequently impossible to heat that room.

But the difficulty can be overcome by providing a proper outlet, of the proper size and in the proper location.

Nothing has done so much to injure heating with hot air as the common idea that neither skill nor scientific knowledge is needed in connection with it. The system has been neglected by scientific men, and the work is frequently turned over to common mechanics. In many places, the carpenter is given the job of having the house piped, and he turns it over to whoever gets the contract for roofing and spouting. The average man who would not think of laying out a shoe closet in the house he is building without consulting an architect, will give all the directions for putting in a furnace, determine its size, its location, the pipes and the registers. Then he expects the "furnace man" to put in the furnace on plans of the builder's selection, and guarantee the working of the plant.

And strangest of all, there are plenty of "furnace men" who will do it.

No wonder guarantees on the working of hot-air furnaces are worth but little.

There is one point in connection with heating with hot air,

to which I have already referred, in which there is a possibility of great waste of heat. This is over-ventilation.

Take a house in which the loss by radiation from walls is 80,000 B. T. U. per hour, in zero weather.

To maintain the temperature by replacing this loss will require the use of 62,857 cubic feet of air per hour at a temperature of 140 degrees.

Supposing the family consists of six persons, the maximum requirement for ventilation would be 11,800 cubic feet per hour. In this case, we are using 51,057 cubic feet of air per hour in excess of the amount required for ventilation. If this air escapes at 70 degrees and has been heated from zero, it represents a loss of 64,963 B. T. U., or about eight pounds of coal per hour.

In my judgment, the remedy for this is to make provision for recirculating this excess of air.

## DISCUSSION.

Professor Carpenter: In order to open the matter up for discussion I will say a few words. In the first place I wish to express my intense satisfaction with the paper. It brings before us a method of heating which the paper very justly states has been neglected by engineers. I think and believe that very much more can be done with systems of furnace heating than has been done in the past by giving to pipe construction and all the various details much better attention, and by working out proportions in a much more accurate form than has been done in the past. There are one or two things in connection with the paper which, perhaps, I do not understand, or do not quite agree with. One statement is in regard to the theoretical efficiency of hot-air heating as compared with that of heating with steam or hot water. As I understand it, the calculations of the paper are based on a higher assumed theoretical efficiency of heating by hot air than by hot water, said to be due to the fact that the air will be delivered from the hot-air furnace at a lower temperature than is possible when steam or hot water is used. That might be true under some conditions, for instance when the air is to be warmed only to a temperature of 150 or 160 degrees. In that case there would of course be an opportunity of warming this

air and still permitting the air-heating surface to be less hot than that required with steam. For instance, the heating surface with steam must be hotter than the steam which is above 212 degrees, but I think such instances are rare. I think in practice the temperature of a hot-air furnace is usually in excess of that required to supply steam. In such cases I fail to see why we would have any theoretical advantage in the hot-air heater over the steam heater. Now the figures of the paper it seems to me are open to considerable question, as to their application; not as to their accuracy at the time the observations were made, but as to the interpretation. In the operation of any heating systems, the apparatus works somewhat like a large fly wheel; if you were to measure the force given off by a large fly wheel, and the force put into a large fly wheel at different instances of time, you would at some time believe the fly wheel was apparently running itself, since it would be giving off a great deal of force and nothing would be going into it. At other times the reverse condition would appear. The same thing is true so far in the working of a heating apparatus. At times it absorbs heat, and we burn a great deal of coal merely to get it hot; then that heat is given off and the reverse condition is true; the heating apparatus is giving off more heat than it is receiving. In the paper the observations show the heating apparatus giving off more heat than it is receiving, it shows the smoke flowing out at 20 degrees temperature, and the hot air warmed by the heating surface passing off at about 210 degrees. Such air operation could not have continued very long with those relations of temperature. If, for instance, the test had been made for 24 hours, or even ten hours, the temperature measurements I feel quite certain would have shown a considerable excess of the flue temperatures over that of the heated air. That I feel must be true from theoretical considerations as well as from my large experience in making tests. I feel with the author that the systems of hot-air heating may be very much improved, and that excellent results can be obtained by properly proportioning the surfaces. He calls attention to one interesting thing at the latter part of his paper, and that is, that in the heating of air for the ordinary use of a house an amount considerably in excess of that required for ventilation is warmed; and I think his advice is very good, that in such instances it would be wise to recirculate

this air and thus avoid loss of heat due to excessive ventilation. That is done very easily, and I think it will result in considerable saving in fuel.

Mr. Thompson: I am very much obliged to Professor Carpenter for the points he has brought out, and for his kindly criticisms. I confess I felt a considerable amount of trepidation when the veteran on heating and ventilating arose to discuss my paper. In regard to the matter of the possibility of exhaustion of heat, I must explain the principle on which it was worked out. I assume you cannot heat anything hotter than the thing that heats it, but there is such a thing as having continuous process going on. In running a steam boiler you can take your exhaust steam and heat the water that goes to the boiler, and that water may reduce the temperature of the exhaust steam far below the temperature of the water in the boiler. Now in the construction of a heating apparatus if you take your cooling agent, that is the air, in at the hottest portion of the furnace, and then let it progress through that over flues and radiators, which are filled with the cooler products of combustion, it is certain the temperature of the air you deliver to the registers cannot theoretically be any higher, and practically must be very much lower than the temperature of the coolest surface which heats it. But if you reverse that course and have the cold air entering your furnace, surrounded with the exhaust portions of the waste products, you can with the cold air reduce the temperature of the waste products to any degree you please. You can then carry your partially warmed air on to the warmer surface of the furnace, and where it leaves the furnace at the point where the furnace is the hottest, you can have the air coming out of the furnace 300 or 400 degrees, if you want it.

In regard to the professor's criticism concerning the continuity of operation, I want to say that I have made not one, but over 25 different tests, with different styles of apparatuses in this line, and in every one I secured practically the same results. The details varied very much. There were occasionally cases where the hot air was not as hot as the waste. Other cases, and the majority of them, it was hotter. But the practical results were always the same, and I have installed an apparatus, where not for a few hours, but for several winters frequent observations were made, the apparatus being in practical oper-

ation, heating houses for the entire winter, where for the entire winter the temperature of the exhaust, as we call it, was less than the temperature of the hot air. In most of the cases where I have made tests, not all of them, but most of them, the fuel was natural gas. That is my pet hobby. I like to monkey with natural gas better than any other fuel. It is more easily controlled than coal, but I have gotten the same results in proper operation with coal.

The Chairman: Any further discussion?

Mr. Donnelly: I notice Mr. Thompson puts in a great many "ifs" as he says, in his possibilities. I think there are some other "ifs" to be run across in furnace heating which are not in the paper. Perhaps if the outside temperature stayed constant, if the humidity did not change, if the wind changed neither its direction nor its force nor its temperature, a uniform result might be possible. But I would like to ask Mr. Thompson if a heating engineer can control his installation without some very complicated apparatus to automatically take care of some of those changing conditions? Now some forms of thermostatic apparatus might help some, and yet I do not personally know of any such thermostatic apparatus to help the hot air when travelling against the wind; when the wind increases considerably in velocity it lowers in temperature; it always does that when the velocity goes up. Is it possible to install a hot-air furnace and have it take care of the change in the weather, such as we get in any section of the country, without good horse sense and good attention in setting dampers? And does it not necessitate a change in hand regulation, the several dampers in the hot air pipe, under the present state of things? It always seemed to me that hot-air furnace heating needed those hand manipulations so much; possibly that is not the condition now, that something has been devised to help it out. I believe if there was, it would help hot-air furnace heating a very great deal.

The Chairman: Mr. Thompson, can you explain some of those things?

Mr. Thompson: I have never found any apparatus that did not require some sense in the operator as well as the installer. I have found it was necessary to manipulate hot-air dampers to keep off the supply from some part of the house in order to heat another, that is, I have found it would be necessary, under some

conditions, to stop the supply from some part of the house to keep it from being overheated. My experience is, get your coldest room warm enough with register open, and after all your rooms are warm, check the register off, and then it will be all right. Now speaking about the thermostat, so far as my observation goes, it will not meet those conditions, nor are thermostats very thoroughly successful with a coal fire. You can regulate the temperature to some degree by opening and closing the draft; but I have never found a thermostat that would help very much with furnace heating.

Professor Carpenter: I think Mr. Thompson did not understand the theory of my statement regarding temperatures, because he suggests that the heat from the escaping gases may be used to warm entering air. That is true also in regard to steam and hot-water heating. You can use that which goes through the damper for warming entering air as readily in one case as another. The general proposition I stated remains true.

In regard to the use of the thermostat in hot-air heating, I would say that all that the thermostat can do is to open and close certain dampers at certain times. The difficulty has been to get the forces to propel the air into the different parts of the house uniformly, and to make those forces propel the air with certainty, no matter in what direction the wind may be. For such a case the thermostat is entirely useless.

The Chairman: Any further discussion?

Mr. Chew: I think this is too good an opportunity to let slip. Yesterday my committee made its report. Now Mr. Thompson states the possibilities, and shows that they are great. He also shows that before those possibilities can be accomplished there is a lot of preliminary work to be done. The answers to the series of questions of which I spoke, about 20 in number, that Professor Kent and Mr. Oldacre prepared and sent to the members would be a partial solution of the problems which this paper presents, and I hope for the sake of Professor Kent and Mr. Oldacre, that when the members go home they will dig up those questions and answer them, and if they cannot find them, let them apply to the Secretary. He will furnish them another copy so they can show us what they can do after they have made a study of them. I think every member understands that the committee would like to have these questions answered

for the good of the Society. The literature of our Society to-day does not contain a description of a single church heating system, except a blower system; not one with a hot-water, steam or furnace-heating system. It seems to me there are churches enough in this country, if not there will be more by and by, to pay the members to study up church heating a little and provide the Society with a paper that will show us the practice at the present time. There is nothing, I will say again, which would increase the value of our Society, and the literature, like a detailed description of a working plant, whether it is an exhaust system, a vacuum system or a hot-air system, or any other system of heating. Professor Kent has asked me to tell you that he would like to have questions submitted on hot water and steam heating, so as to get all the data obtainable on those subjects. Every member of the Society will do good work if he will give the details of some working plant, the amount of glass, etc., and all the details, and eventually we will have a class of information that will be invaluable for reference, and enable some tables to be formed, some books to be made up from them. Now to come back to the point at issue, if you will answer the questions of the Committee for collection of data on furnace heating, you will help the thing along very much. It will be of great assistance with the work, which this paper suggests.

Mr. Folsom: I believe we had better commence educating the architects along with the furnace men; let us talk to them and make them understand it; let us make them understand they have to follow our instructions, that we can set furnaces properly and we know it. Of course, we take the jobs if we can get them. But the architects, more than anyone else, ought to understand them.

Mr. Stangland: It is my experience with this matter that the furnace man gets some information that is useful to him, and he will then see the architect. It is his business to see the architect. Let us educate the furnace man; the architect will take care of the job all right. Let us educate the furnace man.

The Chairman: Mr. Thompson, under the rules you are entitled to make the closing remarks.

Mr. Thompson: I will be very brief. My observation in regard to educating the architect is that the architect can be

cared for all right. Let the heating engineer do the heating, and the architect do the building; that would be all right.

I want to tell you of a practical case I had two or three years ago, and which has been in operation two winters now. A man had a house upon the top of a hill—not what you Chicago people call a hill, but what we call a hill in Ohio. It was on the northwest corner, and faced northwest. Dimensions of the house were about 35 x 35 ft.; I forget the exact figures. It had a kitchen at the back, was two stories high, and on the northwest corner of the house he had a reception hall. That reception hall was about 16 feet square. It had a window in it, and he built a tower out on the northwest corner extending out beyond the corner of the hall, so that the hall, from its extreme dimensions, was 19 feet to the edge of the tower, and 20 feet to the edge of the tower respectively for the two inside walls. It had the regulation winding stairway leading to the upper story. He put five big windows in this tower and a glass door in front, and a window up in the stairway—a good place for the hot air to get out. Well, he struggled along with that house for a good many years trying to heat it with stoves. Everybody told him that he could not heat it with hot air. I went to work on that house and—I am afraid I will spoil my reputation, what reputation I may have, by telling you what I did. You must recollect this was a natural gas furnace, in the cellar; he had a tight basement which had no ashes nor coal in it at all. I set the furnace underneath as near the middle of the house as I could, and I struck those four downstairs rooms in a group with four pipes close together. I gave the reception hall a 12-inch pipe, on a straight line; then I put in the tower close to the window a 9 x 12 return flow register, which I opened into the basement; didn't make any pipe connection. I fitted two other rooms in the same way. That left the hall with an automatic arrangement. All I had to tell him was, "Keep your cellar reasonably closed up." That tower is always the warmest part of the house now. I promised him before I went in that his three pretty girls should use that tower as their sitting room that winter. They did it, and they have done it for two winters. The register is in the corner farthest from the tower, and my cold air return is in the tower. My observation is I can get the best heat in the place where I take the air from.

I had one case of a church which had been a pretty hard problem. I had to put a hot-air register at the entrance end of the church, and the only place I could get any ventilation register was in the stack under the steps of the pulpit that led into the ventilating stack. The first kick that I had was from the preacher who insisted he was too hot. I had to go down to the janitor and we had to practically close up this register under the pulpit so as to quit taking air out.

Then I had another job: I was called on by a personal friend who had some difficulty in heating an old house, and he wanted the work done one way and his wife had her notions, and their ideas on that point didn't jibe. His wife wanted the hall heated, and I think the hall ought always to be the key to the whole situation. He didn't want it, because he said it would be a waste of heat, and there was quite a family argument. I went to her and I said: " Mayme, don't you worry; I will get that hall of yours heated, and it won't take any pipe, it won't be necessary to put any pipe in there." I went to him and I said: " Fred, I will tell you how to do this job, and do it right, and I will not hurt the hall; I will put a 20 x 24 register in it now, and that will take the air from the hall to the furnace." I told him he could save a whole lot of heat, and that is what he was after, so I put in a 20 x 24 register in the hall, and I told the wife to keep the hall door open and she says that that is the warmest place in the house now.

## CXLIX.

# SHEET METAL RADIATION.

BY H. W. NOWELL.

Sheet metal radiation has been in use for over fifty-four years, and in its varied forms is well known to be of more value as a heating agency than any other form or type of radiation. Undoubtedly one of the most efficient forms was the flat wall radiator invented in 1854, and one of more recent date in corrugated form, made in France, both of which are still being manufactured on special order. The writer has knowledge of these that have been in actual use for over thirty-nine years, and the efficiency and apparent durability has not in any manner depreciated. The sheet metal radiator made in this country, which, as before stated, was invented in 1854, was originally made of Swedish Bloom iron and buttoned together on its flat surface with copper rivets. The originals of this first line are in use to-day, but when other makes of radiation came into the market, the manufacturers of this radiator, in order to compete with the price, used a cheaper grade of metal which was apparently Bessemer steel and riveted with iron rivets. The life of these was very short. They were not galvanized; were made entirely by hand, and lap-jointed around the edge and soldered. The corrugated French radiator was made in a similar manner, riveted at the alternate points of corrugation. The writer has no record of the life of these, except a statement made by a manufacturer that he knew of their being in use for over thirty years. There was still another made up in tubular form, tube within tube, which was designed and used in Philadelphia twenty-eight years ago, and the writer knows of some of them still in use and claimed as giving better results than any other type of radiator.

The many different types of sheet metal radiation are conceded by engineers to be the most efficient, but questions have arisen regarding the durability, and pressures which they

would stand, and along these lines the writer has had tests made of the metal used in the manufacture of a number of these, and chemists making the analyses and tests make unqualified statements that there should be no hesitation in guaranteeing this metal for any number of years.

Among the different types of sheet metal radiators, and the most modern, is one made along the lines of the cast radiator, in that it is of a vertical sectional type, and conceded to be more symmetrical and pleasing to the eye as to finish and design than other types, and have been demonstrated to stand 30 to 50 pounds pressure without leakage or bulging. Other features which appeal to the architect, engineer and steam fitter are the lightness and space occupied by the sheet metal radiator, as the weight is about twenty-five per cent. of the cast, and space occupied about one-half. As to efficiency in comparison with cast and wrought tubes, some exhaustive tests have been made, and I will take pleasure in mailing a copy of these tests to any member desiring them.

Some time in the year 1862 Professor Silliman of Sheffield Scientific School, New Haven, made tests which were published, of the flat wall radiator. The efficiency was far beyond that of the wrought tube radiator made at that time.

The sheet metal radiator made at the present time is manufactured of No. 18 and No. 20 metal, and the joints are pressed under heavy pressure, no solder is used—the inside and outside of each section is completely covered with spelter, which prevents oxidation, after which the sections are assembled by male and female joints expanded together as a boiler tube is expanded into a boiler tube head, and the mechanical construction is such as to preclude any possibility of breakage by reasonable pressures, such as are used on present heating plants.

This paper is not written for the purpose or intention to advertise any distinct line of radiators, but purposely to bring forward a line of discussion or argument relative to the merits of sheet metal radiation, and for the benefit of all to receive what enlightenment we can on this class of radiation.

## DISCUSSION.

Mr. Jas. Mackay: This question of sheet metal radiation is one of very general interest. I happen to know something

about making radiators of sheet metal, and think that there is no question whatever as to their efficiency. The doubt in my mind is the question of permanent durability. I have made sheet metal radiators of galvanized iron, of Swedish Bloom and Black Charcoal iron, and almost every other kind. We have used them with exhaust steam, with low pressure steam, and in all manner of ways. The difficulties we met with were the details as to the connections, and the permanent durability of the metal. We were unable to find any sheet metal except copper that stood for any great length of time. And still we have examples of them in use for 20 years. Still I know of others that have given out in two years, and the great majority of them give out inside of five years. Copper ones are better, they wear better and are very durable; everything as to their efficiency and general utility and lightness and compactness were all there. But the question of durability was the one problem we were up against and were unable to solve; we carried those goods in stock, kept them before the public for years and years, and finally abandoned them. Ours were used for heating with fans and for drying paper pulp and confectionery and fruits and things of that kind, and our trouble was simply one of durability. The other features were all there.

The Chairman: Any other discussion? Any other gentleman who has anything to say.

Mr. Jas. Mackay: I would like to add that Mr. Nowell's completion of this paper would be very desirable. I would like to see the results of the tests he speaks of. I think there will be ample time for him to furnish them to us.

I don't think this article is subject to criticism. I am only giving my experience with similar materials. I remember the old Gold Radiator, and think I know of some of them being in use to-day that have been in use for 30 years, and are in pretty good condition now, but they are set up on edge, and the feature of moisture is practically eliminated. The conditions are much better than are usually met with. It is to be hoped that you have overcome the difficulties that we encountered, and which we were unable to overcome. I do not mean to say that you cannot make a sheet metal radiator that will be durable.

The Chairman: Is there any further discussion?

Mr. Morgan: I have had some dealings with the old Gold

Radiators. I remember the time when the soldering iron was a part of the steamfitter's kit. While it is a fact that a great many of them did stand for a good many years, it is also a fact that a great many of them did not stand up but a very short time. There is one question I would like to ask and that is this: Is not the proper test of a radiator by the pounds of water of condensation? I would like to ask if that is not Professor Carpenter's formula for the test of the efficiency of a radiator?

Professor Carpenter: Yes. I understand that the tests which are now in progress of this radiator will be a test of that character.

Mr. Nowell: Yes.

Professor Carpenter: This present test which was just referred to was a test for showing the relative capacity. One cannot get at the efficiency except by measuring the actual heat that goes into the radiator, and that you can only get by weighing the steam that is condensed.

I think we all would be pleased to obtain a light weight radiator; but I also think we can fairly raise the question of durability. It is difficult to make any artificial test that will be a substitute for the durability test of actual use. The use of light metal under the conditions of use will require perfect protection from the effects of corrosion. In the buildings of Cornell University we find that the present cast iron radiators are far from durable and that we have had large repair bills. The troubles are due to the giving out of the nipples which connect the sections of the radiators. I would not like to put any figure on the average life of a radiator, but after one has stood and been in use for five or six years we begin to find repairs necessary. We are also having a great deal of repair work to do on return pipes in the buildings. In some places the conditions seem to be very bad, and we have not been able to find the cause. I know one particular building where we had to take out many of the return pipes on an average of once in two or three years. They would be simply eaten full of holes. We are laying our troubles to steel pipe. Possibly that is not the case at all. I merely mention this fact to show that the present means which we use to heat our buildings are not very durable, and there is a very great opportunity for improvement along the lines of durability for pipes as well as for radiators.

Mr. Donnelly: I would like to ask Mr. Nowell if he cannot read his chemist's report, what is the practical composition of the iron he uses, if he wishes to give it, because I think it would be exceedingly valuable in helping us to judge of its durability; and also the chemical composition, so far as he chooses to give it, so that we may have it as accurately as possible a part of the record.

The Chairman: Can you answer that question, Mr. Nowell?

Mr. Nowell: The only way I can is by reading the report, and perhaps under the conditions it would be better to publish it with the other tests, Mr. Donnelly.

The Chairman: As I understand it, the report is an expression of opinion of the chemists.

Mr. Nowell: Yes.

Mr. Donnelly: Would it not be possible to give the composition without the expression of the chemist's opinion?

Mr. Nowell: No.

Mr. Donnelly: I don't know why the chemist's opinion should not be part of an Engineering Society's Report; but it may not be, of course.

## CL.

## TOPICAL DISCUSSIONS SEMI-ANNUAL MEETING.

### TOPIC NO. 1.

"Can Pipe Size for Risers and Radiator Connections off Risers be Reduced?"

### TOPIC NO. 2.

"Can Area of Mains in Overhead Systems of Hot-water Heating be Reduced with Benefit?"

The Chairman: Mr. Munroe wishes to say something about topics 1 and 2. I see some of the hot-water men have gotten back here now.

### DISCUSSION OF TOPICS NOS. 1 AND 2.

Mr. Munroe: In the East there has come about a great change: there has gradually been an increase in the sizes of mains and risers used. Fifteen years ago it was the practice to install a plant with two pipe connections, each radiator having a ¾-inch and ½-inch connection, even though they contained 100 square feet of surface and they got results, when there were no traps in the mains. You know in the East we scarcely ever use one-pipe work as they do out West. Whenever a job is laid out it is always laid out by an engineer as a two-pipe job. Even now, the sizes of the radiator connections and risers are being guessed at, and the fact is that the men who do indifferent work are always getting the size of the pipe wrong. Yet I have known jobs to be put in where the size of the pipe was very much reduced under that laid out, and if they were put in by practical mechanics good results were invariably obtained. I believe that the sizes now used in many cases are in the interest of pipe and rolling mills rather than in the interest of the purchaser. You can often get along with smaller pipe where you have the proper boiler and radiators. I do not believe it is ever necessary to use so large as a 2-inch valve on a one-pipe

radiator connections with a 90-foot capacity. I may be mistaken, and I want to know how you find it in the West, where you do so much one-pipe work. Is not, as a rule, a 1¼-inch connection on the radiator of 75 feet ample? I am doing some work on a building now, which is a six-story building with 8 radiators averaging 50 feet each; the risers start off from the overhead system, one 3½-inch pipe. It strikes me that with an inch and a half valve at the bottom of the riser conveying steam to 480 square feet of surface, as good results could be obtained by starting the riser with not over 2½ inches.

Mr. Gifford: I think the question is largely one of pressure at which you wish to circulate the steam.

Mr. Munroe: We are presuming five pounds.

Mr. Gifford: Well, for five pounds I think Mr. Munroe's size would give satisfaction. I think the old jobs put in years ago were not put in for high pressure work, but were put in at a time when the amount of back pressure on engines and pump supply exhaust steam was not considered, and I think the increased pipe sizes of the last few years have been along the line of keeping down the back pressure on engines supplying exhaust.

Mr. Donnelly: I am glad this subject of pipe sizes has been taken up. I think Mr. Munroe has the right ratio, and that 75 square feet is all right for inch and a quarter pipe. By the table I use it figures 18.5 feet velocity per second of the steam. In looking over the steam sizes as given in many books on heating, probably the first that was figured out that we took much account of in this country was in Mr. Baldwin's book. His experience in sizes probably ran as the plants ran in those days; there were few steam mains larger than 4 or 5 inch pipe; that was quite a large plant in that time. The velocity which he used in figuring the rule with which we are all familiar, 1 inch for 100 square feet, 2-inch pipe for 400, 4-inch pipe for 1,600, was 40 feet per second in all sizes. Of course if you use a velocity of about 40 feet a second in a 3, 4, or 5 inch pipe you get a good result. In figuring the velocity of steam in pipes they formerly took very little account of the different size of the pipe until the publication of the Babcock formula in this country, which used a different factor of friction for different diameters of pipe. I was particularly interested in this from the very

opposite reason that Mr. Munroe was, that some people who have installed exhaust heating systems say they get a vacuum that does so many wonderful things because of the smaller pipe sizes which they use. The sizes that they have used cause all the way from 80 to 250 feet per second velocity; I think some have used a table with 100 feet per second velocity, but they take off 20 per cent. for a factor of safety, which makes it 80 feet velocity. They build plants with their pipes all the way from ¾ of an inch to 12 inches figured on the same velocity. When they use 8, 10, and 12 inch sizes, their sizes may be reasonable, but when they get down to a 1-inch size and say that 250 or 300 square feet is proper with 1-inch pipe, and that it is good practice, I don't think it is. It is making a very high loss in the efficiency of the radiating surfaces to cut down the diameter of the steam connections to such small sizes.

In this connection I tested with a water column last winter an installation in New York. There were several old buildings and one new one and the specifications called for not more than 4 pounds pressure to be used. It was supposed this pressure was necessary on account of the poor character of the piping in the old buildings. The new piping was supposed to be better than that. The specifications was afterwards changed to a vacuum system and the size of steam connection cut down in the new building. I tested the old work about 300 feet away from the source of supply, and found a drop of pressure only six inches of water column. In the new building, with reduced sizes, yet sizes approved by some people in advocating this system of heating, the drop in pressure ran as high as 20 to 22 inches of water column per 200 feet run; so that that confirmed me a great deal more in my opinion that the larger sizes were a good thing, and it was not good engineering to cut the sizes down.

Secretary Mackay: I noticed the remark made about radiator manufacturers keeping the radiator connections large. I don't think any engineer ought to feel that way about it, because the radiators are usually for a variety of places, a variety of sizes of connections, and all radiator manufacturers will furnish radiators in any way that the steam fitter or heating engineer wants them. The fact that they can furnish them for low pressure steam heating, tapped one inch up to 28 feet, some say, some say

30; or 1¼-inch up to 56 feet, some say 60 feet, should not have any weight with engineers at all. They should make their sizes to suit the work. I think a good many lose track of their subject, confounding it with sizes used in some other system. I have seen very good engineers who were addicted to the vacuum systems, and designed low pressure heating, that got sizes that were too small, and it made trouble for them. They neglected to remember that they were returning against pressure instead of into a vacuum, or into a receiving tank, or into the air, and that they could work with much smaller sized pipe and get good results. I think the most trouble that we experience in sizes of pipe is in the low pressure gravity return system, where the return goes back to the boiler against the pressure of the boiler.

Mr. Munroe: My idea in bringing up this subject was to the end that a table, by which we should all be governed as members of this Society, be adopted; and to that end I would suggest that a committee be appointed to prepare such a table, say on the basis of five pounds steam gravity return, and one pound gravity return, and exhaust heating work, where a minimum back pressure is going to be a feature. I think we ought, as a Society, to determine among ourselves on a table such as I suggest, which should be strictly adhered to. The table might suggest the minimum size that could be used with proper results. I think there is too much leeway on either side. There is always a tendency to cut sizes even beyond what should be done. On the other hand, I know of engineers who make up this work, who, knowing that tendency, have gone to the other extreme and made the sizes much larger than is necessary, making the job extremely expensive. For instance, when you take a building with say eight stories and start with a 3½-inch riser through every room in it, if that could be reduced practically, it would be a great benefit. If that form of table were gotten up and if we were to bind ourselves to use this table, we would have obtained a result and have a standard to go by known as the standard of "The American Society of Heating and Ventilating Engineers," which would be recognized in time. There are so many tables made by so many men with different ideas at the present time, that they are confusing. That is what I'm getting at. I have my own table which I compiled myself, and which I use; and

I can find a number of tables, but they vary so, and I think it would be the proper thing for us to formulate our own table, and give it to a committee of men who have dealt with this subject. I make that suggestion and think it ought to be acted upon.

The Chairman: Suppose you make the motion that it be referred to the committee on standards?

Mr. Munroe: I move you, sir, that this matter be referred to the committee on standards to prepare such a table as I have referred to. (Seconded and carried.)

Mr. Morgan: I think I can help Mr. Munroe out a little. I am familiar somewhat with the practice in the East with 2-pipe work, and I know considerable about the single valve system we use in the West largely. I think the original idea of the single valve system was to combine both sizes, the two sizes usually used in the East, into a single pipe, and just avoid running one extra pipe. In our practice here we used to use nothing smaller than one inch, and on that we would put nothing larger than a 20-foot radiator; up to 50 feet we would use 1¼; 1½ for 50 to 75 feet; a 2-inch pipe for above 75 feet.

Mr. Munroe: With a single pipe?

Mr. Morgan: No, single valve system, in 2-pipe work. I have in mind in the City of Chicago an apparatus which has three 80-foot radiators with inch and a quarter risers, with ½-inch return, and it works very nicely; there is no difficulty at all. That is a good deal of radiation on inch and a quarter pipe, and in 2-pipe work it is entirely feasible. For instance, Mr. Munroe spoke of running 3½-inch overhead system risers down and ending in 1½-inch return; it is my opinion that an inch and a half pipe for fully 100 feet would be just as good as 3-inch pipe, because there is no conflict between the steam and the water. The water is always going ahead, and it is always travelling on its downward course.

Mr. Munroe: That is the exact condition I have before me. I think the plan was prepared by a member of our Society, and why he should name 3½-inch risers in a job ending with 1½ for only 480 feet, I can't understand.

Mr. Morgan: Well, I can tell you a little experience I had. We had recently an old building, a 3-flat building, which had a continuous circuit running out to the centre and going both

ways. The return pipe in both cases was 1¼ in., while the feed pipe was 3 inches. In the rear of the building, because there was not so much radiation, it circulated very nicely, but the front end of the building having the most radiation, there were one or two radiators that would fill up with water. Both of these mains came back with a 1¼-in. pipe. We first separated the mains and put one return in on one side of the boiler and the other return in on the other side; but we found no benefit to the front end of the building. We then laid a 2-inch pipe from the front main, and thereafter had no further trouble. I think one mistake that is being made in the single valve system is about the reduction of the returns to too small a size. I think it would be a better practice to start with 2½ inches and have a 2-inch return.

Mr. Walker: Did I understand you to say that you fed three 80-foot radiators from 1¼-inch riser, single pipe?

Mr. Morgan: No, sir; they also were connected with half-inch returns.

### DISCUSSION OF TOPIC NO. 2.

The Secretary: I might say that my experience has been that you can do overhead hot-water work with a smaller area of mains and drops than you can with the bottom feed or the upward feed. In general practice, the difference was somewhere in the neighborhood of 25 per cent., and I think that the sizes that are in general use all over the country to-day are the proper sizes, from good engineering experience; and that we are running pretty close together. To reduce below those sizes would be an experiment, and as good results would not be obtained as where the engineer in charge used the present sizes. The present practice, in my mind, is about right. I was called in in connection with a good-sized apparatus, overhead supply, where outside of one defect—that the expansion tank was located very close to the level of the horizontal main, which allowed them to boil the water and overflow the tank before they could get circulation to the extreme ends of the mains—the reduced sizes of the connections to the radiators below the present practice prevented them from circulating properly and was affecting the efficiency. When those were taken out and enlarged, the same radiators, with the same overhead mains, operated with the

same boilers, supplied the entire building perfectly. I think in that case they were too small. That is my advice against running into the same mistake.

### TOPIC NO. 4.

"What is the Best Material for a Gasket in a Flange Union for Hot-water Piping?"

Mr. Harvey: I think a ground joint would be the best.

The Secretary: Why, Mr. Harvey?

Mr. Harvey: Because you would have the two best facings which could be made.

Mr. Donnelly: Professor Sweet in his work says that "If an honest man has an honest lathe and does an honest job he don't need any packing." It seems to me it is pretty hard on steam-fitters. Of course, they are not all machinists. He says with the cylinder head turned off—you don't have to grind it; if you have the right kind of a tool and the right kind of a man who takes the finishing cut, you can take it apart and put it back again, and it will still stay tight. I never make a flange union that way for hot-water work, but I remember some who used to try thin packing, but it would not be tight because the surfaces didn't meet; they would have to increase the thickness of the packing, and I have seen it a quarter of an inch thick. I think Mr. Harvey is right, that the surface to surface method is the best.

Mr. Jewett: We have used "Rainbow" and "Ruby" both for packing 1-16th of an inch thick on flange union joints for hot-water works for the past ten years, and have had no fault to find at all. In small piping we never use thicker packing than 1-16th of an inch. With the commercial flange union, as found in the market, and with flange fittings, we have had no difficulty or trouble.

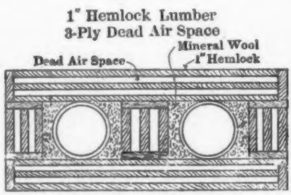
### TOPIC NO. 5.

"The Protection of Underground Piping."

Mr. Barron: In the second volume (1896) of our Proceedings there is a paper by Professor Carpenter on this subject; and in the course of the discussion many methods are brought out. As the problem often confronts the engineer, I think an effort should be made to schedule the various plans followed. In the

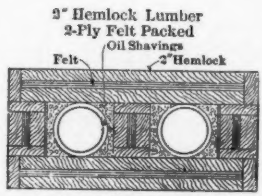
*Street Railway Journal* for May 27, 1905, there is a description of the plant of the Bloomington and Normal Railway, Electric and Heating Co., by Mr. H. Robinson. He says in regard to the underground piping: "They are laid in hemlock conduits, whose bottom consists of three 1-inch boards, separated from each other by side pieces 1 inch thick. On this base the pipes are laid with similar side pieces placed on each side of them. The upper part of the conduit duplicates the construction of the lower; the present style of the conduit with mineral wool or oil shavings has not proven entirely satisfactory, and in future construction the two-ply felt packed casing shown in the accompanying sketch will be used."

I have known of air-space non-conducting covering for thirty years and it is never a success, because it is almost impossible



OLD CONSTRUCTION

FIG. 1.



NEW CONSTRUCTION

FIG. 2.

THE PROTECTION OF UNDERGROUND PIPING.

to prevent air circulation and leakage. It would seem to me that a trench for the pipes with a 6-inch cement bottom and 8-inch side walls and the board and felt cover, the pipes to be on rollers and covered with felt, would be a good arrangement; but the loss of heat when pipes are run even half a mile is very great.

Mr. Schott: The sketches as drawn are not right. In the lower sketch there, which is termed the old construction, the centre bearing piece should be simply one piece. Those drawings on the board are supposed to represent the Yaryan form of insulation and the Schott Special insulation. The lower drawing represents the Yaryan insulation, it being made up of what is termed 3-ply hemlock, each section being made of 3 hemlock boards, ⅞ of an inch thick each, with ¼-inch air cell between each layer, with materials of the same character and thickness put on

the edge to seal the air cell. The centre bearing piece, or what is intended to assist in carrying the street load, is only one inch thick, instead of being as shown in that drawing. The top drawing is what is known as the Schott Special Insulation, and is made of either two or three ply, depending entirely on whether the mains to be insulated are steam or water, and also on the size of the mains. This is similar in form and character to the Yaryan, excepting where ⅞ of an inch material is used in the Yaryan 2-inch material is used in the Schott system. The air cells are quilted with a special quilting which makes the air cell a confined air cell. The centre bearing piece in this form of insulation is governed as to thickness by the street load conditions. This form of insulation also has the top section placed crosswise instead of lengthwise, so that at no time is there any danger of the insulation breaking down, placing the weight of the street on the mains, leaving the pipes free at all times to expand and contract without any interference of the crushing in effect. With the Yaryan system they usually use as a filler around the pipes, inside of the structure or conduit, treated wood shavings. Formerly rock wool was used, but experience has proven this finally crumbles and is of no particular value in this class of work. The Schott system uses plain soft wood shavings, the pipe being covered with a layer of asbestos to prevent charring, providing they are steam pipes, but in case of water pipes no special covering is applied, as same is not necessary. After the structures are put in place, the tops and sides are treated with asphaltum or pitch, and then a layer of special asphalted asbestos laid over that to seal any openings in the conduit and to act as a water shed to moisture. In all cases the conduit is thoroughly interdrained so that there is no danger of waterlogging the system.

Mr. Davis: I would like to ask Mr. Schott if there is a patent on that construction.

Mr. Schott: Oh, it is like a lot of other things. Some people claimed a patent, and I undertook to trace it down, and I couldn't find where there was anything that interfered with it.

Mr. Davis: You stated that the top construction was yours.

Mr. Schott: That is what I call mine, that is called "Schott's Special." As far as patents are concerned, I made up my mind I would rather keep out of litigation than get into it.

Mr. Bailey: I think the brick wall and the concrete construction Mr. Barron suggests would be a very expensive thing, and not as good as this form of covering, because it would let in leakage.

Mr. Jewett: In a very considerable number of central-station heating plants the underground mains have been covered with the Wyckoff covering, and very excellent results obtained.

This is a hexagonal covering consisting of two layers of one inch white pine boards with a double layer of corrugated building, or felt, paper between. Each layer of wood is wound spirally with galvanized iron wire and the outside is given a 1-16 inch coating of molten asphaltum pitch. The covering is air-tight, water-tight and a very good non-conductor with a double air space.

Mr. Bailey: Concerning the Wyckoff covering Mr. Jewett spoke about, I have run some tests on that covering, and we passed water through about a mile of tight pipe at a velocity of between 3¾ and 4 feet per second, and we got a drop in temperature of a little over five degrees. That was an 8 and 10 inch pipe.

Mr. Schott: With the upper type of construction my usual form of guaranty is that on a mile and a half or 3 miles with the pipe line circulating 60 per cent. of its capacity, I will guarantee to deliver water with a loss of not over 3 degrees or forfeit one thousand dollars for every degree I lose over and above that or get a bonus, and I always get the bonus.

The Chairman: Any further discussion? Professor Hoffman, when you made your test, did you make any test on the method of protecting pipes?

Mr. Hoffman: On neither test did we take into account the difference in temperature between the end of the line and the plant, so I am not able to say in that case what it would be.

Mr. Jewett: In June, 1900 or 1901, there was a paper presented to the American Society of Mechanical Engineers at the Cincinnati meeting, read by Mr. H. T. Yaryan, who designed and used the old construction covering. He described a plant in Toledo, the Floyd Street plant, and stated that in that plant the drop in temperature in the main, from the station to a point 1½ miles from the station, was 17 degrees. In this plant at Red Oak, Iowa, which I mentioned once before, the

water leaving the station passed through the entire circuit about 1 mile long and returned to the station with a loss of one degree in temperature before any radiating surface was connected on the line at all, giving a very good test as to what the loss was on the line. The circulation was about 3 feet per second in the mains.

Mr. Schott: There is one feature that enters into that question of drop, and that is the number of times per hour you are changing the water in your system. You can take a light loaded system and it may be you are only changing your water once in 2 or 3 hours, but when you get to the loaded system you are changing your water once every 20 minutes. You get your greatest drop when operating under light loaded conditions. When your plant is fully loaded and you have the coldest temperature, you get your least drop, so in making tests there is a point that is very flexible as far as arriving at the true facts is concerned. For instance, if under normal working condition you made a test at freezing point between the power-house and the end of the line and certain results were obtained, the same line at 10 degrees below zero would give entirely different results. It is due to the fact that your velocity is twice as great during the minimum temperature as it is at other times.

Mr. Jewett: The system of piping which I have spoken of, the single-pipe system, is entirely different from anything so far described. I did not intend to mention it here, but I will say that we have installed a large number of one-pipe hot-water systems. It is practically the same thing as a one-pipe system in a house. There is one pipe which goes out through one street and back through another or others to the station. That pipe is the same size all the way around the circuit, so that the amount of water in the system may be independent of the amount of radiation on the line. That is, if your pump is producing a certain differential pressure between the suction and the discharge, and your line is a certain length, it will handle a certain quantity of water, whether the water is hot or cold, and whether there is much or little radiation. If there is no radiation on the line, and the insulation is perfect, the water should return to the station at the same temperature it went out.

Mr. Harvey: There is one point I would like to mention here. I have found by experience in carrying steam for running

power, etc., underground, by taking a long sewer crock having 2-inch space between that and the pipe, by having a cast-iron ring at each end of the sewer pipe crock without elbows, and the elbow has a sort of cast-iron ring in which the steam pipe rests, " V " shape, and the section of pipe is practically sealed, so that there is no circulation horizontally; then this crock in that same ring has a bearing on it so that the outside of this ring fits on the inside of a wooden log of 4 inches in thickness of wood on the outside of the log, that gives me a 2-inch dead air space, practically hermetically sealed, and a dead air space on the outside of the crock between that and the inside of the wooden log or wooden pipe of 2 inches—there is 6 inches of air space around the outside of the pipe. I have had occasion to test a pipe, in running a pipe to make a test, and I have had 100 pounds of steam on a steam pipe for 24 hours. I took a box, a perfectly tight box, with a gland in it and put a thermometer inside the box where it could be seen at all times, and the thermometer did not rise in temperature 5 degrees in the 24 hours. That 5 degrees may have been caused by the surrounding temperature, but it was not affected at all by the wood. That was a test I made some 10 years ago, and I think that the merit of the insulation of that pipe was practically in confining the air so that there was no circulation of air horizontally any farther than each length of 3 feet. I might say that I carried steam in that way for over a mile and ran a 200 horse-power engine at the end of that mile and we didn't lose 5 pounds of steam in temperature with the whole of the distance; I had a large receiver at the engine that I ran the steam into, and took the steam from that receiver to the engine.

## TOPIC NO. 8.

**"Are the Benefits from Large Mains with Branches in Hot-air Furnace Systems Sufficient to Merit Wider Adoption?"**

Mr. Chew: It might be of some interest to the members to know that some three years ago Mr. B. Harold Carpenter read a paper on the use of large mains for hot-air furnace work. The method of doing furnace work that he described I know is not practised to any considerable extent in the East. I know that one of our former members, Mr. John G. Sorgon of San Francisco,

uses a large main to start off with the hot-air furnace, a 24-inch pipe, and in some instances running it as much as forty feet, sometimes in directions which furnace men here would claim to be impossible and have it do good work. But he claims to satisfy his customers and he gets his money. He has at least twice the area in the horizontal main that he has in the last stack to be supplied. Mr. Spellerberg I know has frequently used this method in his practice, and instead of running large pipes like that for convenience he arranges to run one large main to supply several branches for more efficient service. This subject is worthy of consideration by the members interested in furnace work.

### TOPIC NO. 9.

"Vacuum System of Hot-water Heating."

Mr. Hoyt: The sketch on the blackboard is a ground plan of my greenhouses and my dwelling which are connected and are heated from one boiler, 20 H. P. of the locomotive type. For convenience I have numbered them 1, 2, 3, 4, 5, 6. Nos. 1 and 6 (dwelling) are at the extreme ends of the plant, the outside measurement being about 126 feet. Nos. 1, 2 and 3 are connected houses, no division wall between them, east and west houses, 60 x 22 feet each, and the dwelling is connected to No. 3 by an office and short passageway. This house, No. 4, is a north and south house, 24 x 84 feet, lying at the east ends of Nos. 1, 2, 3. In the upper story of the dwelling is situated the expansion tank, 30 inches diameter, 30 inches high, elevated next to the roof with a ½-inch pipe leading upward from the high end, in which is an automatic air valve opening from any inside pressure, but closing from any outside pressure. All the pipes in the greenhouses discharge their air into this expansion tank automatically. This valve is simply a ½-inch union with a solid gasket and screwed tight enough to just leak a little. This leak will insure the discharge of all the air from the inside of all the piping. One 6-inch main leads from the boiler slightly uphill through the west side of house No. 4, reducing to 5-inch, then to 4-inch about the centre of the house, thence outside of the house at south end, underground 20 feet, thence with one elbow it enters the dwelling cellar 20 feet farther. Houses Nos. 1, 2 and 3 are each fed by one 2-inch riser from the

main as it reaches the houses and No. 4 itself has one 2-inch riser at the south end. The heating pipes run back under benches to the north or boiler end. The dwelling is fed by one 2-inch riser taken from the cellar entrance of the main for each floor. The first floor has a sitting-room with 100 sq. ft. radiators; parlor 100 sq. ft., bedroom 40 sq. ft., dining-room 80 sq. ft., kitchen 60 sq. ft., and office 60 sq. ft. radiating surface. The office, dining-room, kitchen, and bedroom radiators are fed from one 2-inch riser taken off from main in house No. 4 and enters the dwelling cellar through house No. 3. This is quite a long pipe, about 60 or 70 feet, before it reaches a radiator. The sitting-room and parlor radiators, 100 sq. ft. each, have as return to boiler one line of 1¼-inch pipe. The dining-room and office radiators, 80 and 60 sq. ft., have one similar line. The kitchen and bedroom radiators, 60 and 40 sq. ft., also have a similar line 1¼-inch pipe. The upper floor radiators, five in number, are fed from one 2-inch riser from the main at the cellar entrance, passing through part of the cellar around the wall about 50 feet, then rising to and through the 2d floor at the south or parlor end of the dwelling near the centre of the south wall, thence it branches (1½-inch branches) to the outside corner of the upper room, feeds one radiator on each side of the room, then reduces to 1¼-inch pipe and follows the baseboards line on each side of the upper floor, then drops to the cellar at back or north end of the dwelling and goes back to boiler in one line of 1¼-inch pipe. The three remaining radiators in three different rooms are fed from these two 1¼-inch lines which answer as both floor and return.

The valve in the expansion tank virtually makes an open tank of it as far as pressure from the inside is concerned, but is a closed system from the outside. When firing is hard enough (about 250 degrees Fahr. at the boiler), the tank fills with water, causing the valve to leak slightly, but if the fire slackens down the water recedes and a vacuum is the result.

Here is the result of one day's test: Started with cold water and no fire in boiler at 5 A.M., water in boiler and radiators at 70 degrees Fahr. At 5.15 A.M. the boiler was 78 degrees (all the greenhouses being shut off and only the dwelling on). At 6.30, 190 degrees; at 7.30, 240 degrees. This 240 degrees Fahr. did not make the automatic valve leak, but the glass showed the

tank to be full of water. I took off the valve cap and readjusted it. Then at 8.15 A.M. boiler was 220 degrees Fahr., 200 degrees in the kitchen and sitting-room radiators and 144 degrees in the parlor radiator. At 10.15 A.M. boiler was 212 degrees Fahr., the radiators were kitchen 170, sitting-room 170, parlor 120, and office 164 degrees. At 10.15 A.M. I could get no water out of the kitchen radiator. At 6.30 P.M., 12 hours after the last firing (soft coal and not a large fire), the expansion tank was not full. The boiler was 140 degrees F. The kitchen radiator was 124 degrees, sitting-room 124 degrees, parlor 112 degrees, office 114 degrees. At 8.30 P.M. the boiler radiator was 130 degrees, kitchen 144 degrees, sitting-room 114 degrees, parlor 102 degrees. The temperatures were read thus: Kitchen, after the water has gone through the radiator; sitting-room, as the water enters the radiator; parlor, after the water has gone through the sitting-room and the parlor radiators; office, after the water has gone through the dining-room and the office radiators.

Mr. Chew: You say there was very little fire in the boiler and that the temperature goes down very slowly. What is the cause of the rapid circulation? Is it the result of a vacuum in the extension tank?

Mr. Hoyt: No, sir, not altogether the vacuum, but from the manner of the installation I get the most rapid circulation when the water in the boiler is boiling, whether at 260 degrees or as low as 100 or 120 degrees, and I cannot boil the water at less than 212 degrees without there is a vacuum.

With a vacuum we have a circulation lasting longer in cooling after firing, with faster circulation and a quicker response from a brisk fire than possibly could be had from an open installation or under a pressure or closed system.

Mr. Chew: The system then is virtually an open tank system, and when you fire hard enough you flush the expansion tank; the wall union or automatic air valve on the tank makes it an open tank; but when the fire slackens and the water in the tank recedes the valve closes and a vacuum commences, and this vacuum then is a coal saver by prolonging the heat and circulation from the fire beyond that obtained from the same firing without a vacuum.

Mr. Hoyt: Yes, sir; that is what I have found to be a fact and have had three or four winters of experience with it.

Mr. Donnelly: I would like to know if this system is patented.

Mr. Hoyt: No, sir.

Mr. Chew: From the talk I had with Mr. Hoyt this morning before this meeting opened, as near as I can understand, he claims that by the use of the valve at the top of the expansion tank, he has all the advantages of an open tank system; that the system can be full of water clear up to the valve at the top, and as soon as you fire and expansion takes place and there is sufficient heat, you open the valve and present no obstruction. He claims you can make your fire in the boiler and then as the water shrinks from loss of temperature the valve is tight enough to prevent air entering, and with his water then under a vacuum, or having a tendency that way, he gets circulation that is more lively and has better heating effect than he would with the open tank system. That is what I gather he claims for his system.

Mr. Hoyt: You get stronger heat in your radiators than you would from an open tank system.

## TOPIC NO. 10.

"Is the Present Ratio of Flue Area to Grate Area in Cast-iron Heating Boilers Conducive to Economy?"

The Secretary: Mr. President, I rather think that the idea of suggesting this topic was the opinion that the present smoke outlet of cast-iron sectional boilers was too large for economical results, and for the surface and grate area of the boilers. That is something that is very easily controlled. Most boilers are built with a throttle damper on the smoke outlet; they can reduce it half-way or two-thirds. I don't think there is anything in the present construction of cast-iron sectional boilers about the size of the smoke outlet to make the boiler waste fuel. Still I do believe and have always felt that with cast-iron sectional boilers that have a continuous upward fire travel, from the fire to the smoke outlet, they must be correspondingly as wasteful in fuel as direct draft stoves are to a return flue stove; but I have felt that the boilers we have, with down draft for the gases before leaving the boilers, were the most economical type to use; and if

they had a down draft, the smoke collar being large would not interfere with its efficiency.

### TOPIC NO. 11.

"The Production of Wrought-iron Screw Nipples."

Mr. Barron: Some years ago I published a short article on "Crude Thoughts on Crude Engineering," in which I tried to emphasize the work of Mr. W. C. Baker in advocating clean threads on pipe and fittings and metal to metal joints. Later I read a paper before this Society on "Screwed Fittings," advocating some improvements in their manufacture, with some hopes that engineers at least would be influenced; but as far as I have been able to judge, they never were, so that in writing on nipples I have no hopes that anything I say will have much influence. I confess that like the average constructing engineer, if I could get the lowest discounts from the list, that to me was the important fact of the nipple question and as far as it usually interested me, but the forging of a nipple originally was probably the beginning of the pipe industry and all that has grown out of it. Very few of us ever consider who makes nipples or how they are made. The pipe mills do not bother with them and very few manufacturers of fittings make them. It would not pay them to do so. Those who make a specialty of nipples make it pay by buying scrap pipe or junk only; they rarely use new pipe, I believe. This is why the pipe mill people are out of it. Nipple machines are the ordinary pipe machine with a nipple chuck. They are of the single and double head type, the double head machines being the ordinary double head bolt cutter adapted to pipe work. The nipples are first cut from the stock by a disc pipe saw revolving at high speed between rollers. The best type of this machine is one with the shaft carrying the disc to be as long as possible, say 10 or 12 feet. Some use vertical jig hack saws and some band hack saws and also the reciprocating horizontal hack saw machine that is used for cutting bar iron. A circular steel saw should answer the purpose, but I have not seen them used.

The ordinary cutting off tool is never used in this work, as it is too slow. The old style single head pipe machine, fitted with a lever chuck and a lever expanding die head, makes a

good nipple machine. A man will thread 2,000 1-inch nipples on this in 10 hours.

This machine runs at a very high speed, so does the double head type of machine, and there is very little gain practically in having the two heads, as the output is about the same as the single. The dies for nipple making at high speed have to be made of special steel and have to have large lips and clearance. The ordinary pipe machine die is worthless for this work. Where the regular lever expansion die head is used, if it gets out of order it can be slipped out of place and a spare one substituted in a few minutes, but if chaser dies are used in a fixed head, it is a very slow job, changing dies; this is true of the bolt cutting type of machine. Pipe of standard weight and thickness is not best for the nipple maker; it suits him better if the pipe is a little under the standard in diameter: but he has to take what he can get. It would seem that a special design of nipple machine would increase the product, but as far as I have observed the special machines that have been tried are more or less failures. Getting out nipples is high tension work, and there is no such thing as inspection of the product, except in a general way. The remarkable thing is that on the whole they are so satisfactory and cause so little trouble.

Whether it is within our province to discuss the manufacture of nipples, I am not sure; but it interests many of our members. If this subject is deemed legitimately in our province, I would like to see various cuts of the special machines for this work illustrated in our proceedings; this would show the state of the art at a certain time and be useful to the searcher. Our work is to advance the art; it would seem that a matter of this kind becomes our work.

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Jones, Walter, Holly Mount..........Stourbridge, England.
Joslin, H. A., 1133 Broadway..................New York.

Kauffman, Samuel, 1510 Clark Ave...........St. Louis, Mo.
Kehm, August, 226 E. Kinzie St...............Chicago, Ill.
Kellogg, Albert T..........................Kewanee, Ill,
Kenrick, Alfred E., 214 Washington St.
(Pres., 1902).....................Brookline, Mass.
Kent, Prof. Wm., 601 Comstock Ave.
(Pres., 1905).....................Syracuse, N. Y.
Kinealy, Prof. J. H., 619 Granite Bldg.
(Pres., 1901)......................St. Louis, Mo.
Klemm, J. George, Jr., 420 Arcade Bldg.....Philadelphia, Pa.
Kries, H. A., 301 N. Howard St.............Baltimore, Md.

Leek, Walter...........................Vancouver, B. C.
Lewis, Samuel R., 433 Wabash Ave............Chicago, Ill.
Libby, L. R., 164 State St................Hartford, Conn.
Lisk, J. P., P. O. Box 505.....................Troy, N. Y.
Loeb, H. A., Broad & Wallace Sts..........Philadelphia, Pa.
Lyman, C. M., 44½ Miller St.................Utica, N. Y.

Mackay, James, 1200 Michigan Ave............Chicago, Ill.
Mackay, W. M., 235 Water St. (Pres., 1897)......New York.
Maguire, Wm. Robt., 10 Dawson St.........Dublin, Ireland.
Mallory, H. C., 100 Broadway.................New York.
Mappett, A. S., 380 Bourse Bldg...........Philadelphia, Pa.

McCann, Frank G., 500 Park Ave...............New York.
McGinness, J. E., 541 Wood St...............Pittsburg, Pa.
McGonigal, Wm., Fairfax Bldg..........Mt. Vernon, N. Y.
McKiever, Wm. H., 292 Avenue B.............New York.
McPherson, Chas. J., 47 First St.............Portland, Ore.
McPherson, W. C., 47 First St...............Portland, Ore.
Mechling, F. M., 541 Wood St...............Pittsburg, Pa.
Mehring, Geo., 24 Sherman St................Chicago, Ill.
Merritt, Jas. H., 48 Cliff St.....................New York.
Meyer, Henry C., Jr., 1 Madison Ave............New York.
Miller, Oliver, 122 E. Culton St..........Warrensburg, Mo.
Mobley, Edw. S., 100 W. Patrick St..........Frederick, Md.
Morrin, Thos., 351 Frederick St..........San Francisco, Cal.
Mott, A. C., Amer. & Dauphin Sts..........Philadelphia, Pa.
Muellenbach, H. W. E., 6 Buesch Str....Hamburg, Germany.
Mulford, Clarence C...................Coram, L. I., N. Y.
Munroe, Edwards K............Gavanstown, Baltimore, Md.

Neal, Ambrose O., 161 E. 84th St...............New York.
Neiler, Samuel G., 1409 Manhattan Bldg........Chicago, Ill.
Nesbit, D. M., 12 Great James St. Bedford Row, London, Eng.
Newton, Chas. W., 1202 W. Fayette St.......Baltimore, Md.

O'Hanlon, George, 328 E. 30th St...............New York.
Oldacre, C. E., 1629 Sansom St............Philadelphia, Pa.
Osbourn, Millard P., Point & Elm Sts.........Camden, N. J.

Patterson, N. L., 710 Tribune Bldg............Chicago, Ill.
Patterson, W. S.........................Appleton, Wis.
Paul, Andrew G., 622 Warren St..............Boston, Mass.
Payne, John A., 33 Clendenny Ave.........Jersey City, N. J.
Pope, Wm. A., 79 Lake St...................Chicago, Ill.

Quay, D. M., 716 Townsend Bldg. (Pres., 1900)...New York.

Reck, Anders B., The Reck Heating Co., Ltd.,
Lyng-by-gade, Copenhagen, Denmark.
Reed, Alvin D., 3126 Rutger St..............St. Louis, Mo.
Ritter, H. H., 47 E. 18th St...................New York.

Robinson, Harry A., 1409 Manhattan Bldg......Chicago, Ill.
Rouquaud, Lucien, 88 Ave. Victor Hugo.......Paris, France.
Russell, Joseph N., 22 Charing Cross......London, England.
Rutzler, Enoch, 127 White St...................New York.

Sabin, Fred'k, 121 N. 2d St...............Philadelphia, Pa.
Sadler, John T., 122 Lake St.................Elmira, N. Y.
Schaffer, John P., 209 Wood St..............Pittsburg, Pa.
Schlemmer, Oliver, 1050 Hulbert Ave.........Cincinnati, O.
Schlemmer, Oliver H., 1050 Hulbert Ave......Cincinnati, O.
Scollay, U. G., 76 Myrtle Ave..............Brooklyn, N. Y.
Scott, Geo. Welsby, 1301 Security Bldg.........Chicago, Ill.
Scott, Robt., 1716 Ludlow St..............Philadelphia, Pa.
Sekido, Kunisuke, c|o Takata & Co...........Tokio, Japan.
Seward, P. H., 76 Centre St....................New York.
Shanklin, John R.....................Charleston, W. Va.
Sherman, L. B., 713 Park Row Bldg.............New York.
Smith, H. A., 160 Fifth Ave....................New York.
Snow, Wm. G., 1108 Penn Mutual Bldg........Boston, Mass.
Snyder, C. B. J., 500 Park Ave.................New York.
Sparrow, Ernest P., Hartford Rubber Works Co.,
New Brunswick, N. J.
Stangland, B. F., 45 Fulton St..................New York.
Stannard, Jas. M., 63 S. Canal St...............Chicago, Ill.
Stibbs, George H., 1081 Degraw St.........Brooklyn, N. Y.
Still, Fred R., 1400 Russell St................Detroit, Mich.
Stock, Edw. L.......................N. Tonawanda, N. Y.
Stockwell, W. R., Irvington-on-Hudson..............N. Y.
Switzer, Wm. H., 115 Genesee St..............Utica, N. Y.
Symms, Chas. D......................Sioux Falls, S. Dak.

Talcott, R. B., 427 Fifth Ave....................New York.
Teran, Cesar, 50 E. 20th St.....................New York.
Theorell, Hugo, G. T.................Stockholm, Sweden.
Thompson, R. S.........................Springfield, O.
Thomson, T. N., 1033 Ridge Row.............Scranton, Pa.
Tobin, George J., 187 North Ave............Plainfield, N. J.
Traschel, J. C. F., 230 Arch St.............Philadelphia, Pa.

Vanderveer, Chas. P., 118 Fifth Ave..............New York.
Vrooman, Wm. C., 138 State St..........Schenectady, N. Y.

Waggoner, E. P., 59 13th St................Hoboken, N. J.
Walker, J. J., 8 Wood St....................Pittsburg, Pa.
Washburn, Wm. S., 60 State St..............Boston, Mass.
Waters, T. J., 710 Tribune Bldg................Chicago, Ill.
Welsh, Harry S., 5 Birr St................Rochester, N. Y.
Weymouth, Geo. H., 259 Front St..............New York.
Widdicombe, R. A., 1651 Roscoe St............Chicago, Ill.
Williams, F. A., 211 W. 20th St.................New York.
Wilson, H. A., 236 Congress St...............Boston, Mass.
Wilson, J. J., 2023 N. 25th St..............Philadelphia, Pa.
Wing, L. J., 136 Liberty St.....................New York.
Wolfe, Wiltsie F., 668 The Bourse (Pres., 1898),
Philadelphia, Pa.

Yates, Walter......Parksend, Swinton, Manchester, England.

Zeck, Alex.............................Grafton, W. Va.

ASSOCIATE MEMBERS.

Allen, John K., 64 N. Jefferson St..............Chicago, Ill.
Birdsall, Wm. A., 675 Hunterdon St...........Newark, N. J.
Corbett, Frank J., 126 Liberty St................New York.
Gates, Howard T., 46 E. 20th St.................New York.
Gombers, Henry B., 260 W. Broadway...........New York.
Graham Joseph, 1123 Broadway................New York.
Heatherton, Jas. M., 61 Beekman St.............New York.
Jennings, Fred'k W., c|o Ashwell & Nesbit, Ltd.,
Leicester, England.
Kellogg, C. V., 1200 Michigan Ave.............Chicago, Ill.
Larsen, Lewis A., 3931 W. 6th St.............Duluth, Minn.
Martin, Harry S., U. S. Radiator Co.........Dunkirk, N. Y.
Robinson, Stephen W., 12 Great James St.,
Bedford Row.....................London, England.
Smith, F. W...........................Dunkirk, N. Y.
Story, Robt. K., 8 Hancock St.............Brooklyn, N. Y.

## JUNIOR MEMBERS.

Knickerbocker, Jesse P., Amer. Dist. Steam Co., Lockport, N. Y.
Phillips, Lee, c|o Shaw, Kendall Engineering Co... Toledo, O.
Robertson, Geo. A., 438 Lafayette Ave....... Brooklyn, N. Y.
Schlemmer, Edmund, 1050 Hulbert Ave....... Cincinnati, O.
Slotboom, C. M., Wagenstraat 96....... The Hague, Holland.
Thompson, Nelson S., Supv. Arch. Office.. Washington, D. C.

# INDEX TO VOL. XI.